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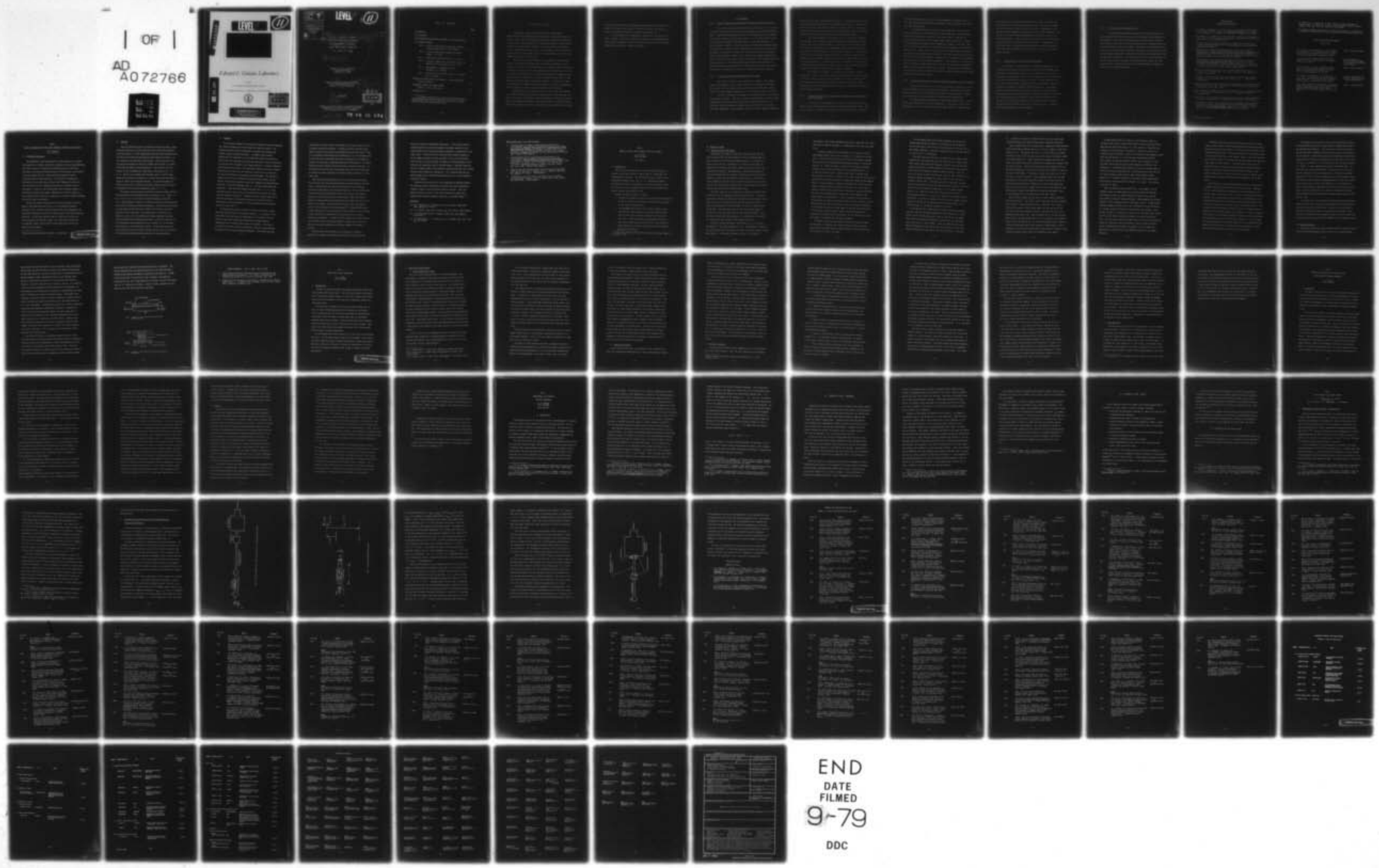

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G.L. Report No. 2950

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Edward L. Ginzton Laboratory of
Stanford University.
Stanford, CA 94305

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Submitted by Marvin Chodorow on behalf
of the faculty and staff of the
Edward L. Ginzton Laboratory

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*A separate *Administrative Supplement* has been prepared for limited distribution which provides the *Significant Scientific Accomplishments* and the *Technology Transition Reports* together with other pertinent administrative data.

INTRODUCTION

This progress report covers work done under JSEP Contract N00014-75-C-0632 for approximately the past year. The contract started on April 1, 1978. Some of the projects had been active under the predecessor of the current contract and some were just started with the current contract. Therefore, there has been no attempt to set precise dates on the period covered. The material covered will be up to the time of the writing of this report (May 1979), which means there will be approximately a year's work or somewhat more covered in this report.

Most projects are concerned with the exploration of some original concept, using special materials and/or electronic interactions in some unique way, with some well defined purposes; for example, possible new kinds of spectroscopy using lasers to make measurements not easily done, if at all, at present, the investigation of superconducting electronic components using high T_c materials, exploration of various techniques and materials for more sophisticated and/or higher speed signal processing. In most cases, there is uncertainty as to whether the material properties, material combinations required and/or the physical processes envisaged can be achieved.

Broadly then, one can categorize most of these projects as aimed at very useful and unique applications by means which are still uncertain, and which will require a great deal of basic investigation of materials, processing, and technological innovation. This has been typical of the work under JSEP in this laboratory for many years where some new possibly useful concept

has been conceived and then the subsequent program devoted to research to see whether this concept could actually be reduced to practise and shown to be actually a possible one given the limitation of materials, etc.

Each individual unit is described in some detail in the body of the report. However, it may be of some value to briefly list and summarize the various projects included in order to provide a birds-eye view of the whole program and its direction. There are six units.

UNIT SUMMARIES

Unit 1 — High-T_c Superconducting Weak-Link Josephson Junctions and Circuits

This unit is concerned with exploring the feasibility of such circuits, the physics of the devices, the fabrication procedures, and operating characteristics. Superconducting integrated circuits are considered to be key elements for the next generation of high speed computers. It is a field which is being actively pursued elsewhere, principally IBM, but with other materials, i.e., low-T_c materials. High-T_c circuits would have very important advantages because of the ability to operate at higher temperatures, and therefore the successful development of fabrication techniques for these materials would be important. Normal photolithographic methods are not suitable, for reasons described more fully in the body of the report, because of the nature of the materials involved. Some alternatives to these methods have been developed which do seem to be successful and offer the promise for the fabrication and testing of the kind of devices under consideration in this unit. Theoretical work also continues.

Unit 2 — Acoustic Surface Wave Scanning of Optical Images

The title listed here is not completely descriptive. The original program was intended to cover a broader area than is signified by the title. On the other hand, the methods which have been pursued in this unit could be applied to optical imaging though this is not the principal thrust at present.

The unit is actually an outgrowth of a previous activity on an acoustic wave storage correlator. That device involved a piezoelectric film (zinc oxide) deposited on a silicon substrate containing a closely packed array of p-n junctions, with an additional overlying electrode on top of the zinc oxide. With that combination, a high-frequency, wide-band acoustic signal, propagating

along the piezoelectric medium could be stored as a charge distribution pattern in the capacities associated with the individual p-n junctions. This could be read out at a later time, hence it would be a storage device or, conversely, successive, repetitive weak signals could be cumulatively stored in the charge pattern to give an enhanced sensitivity for detecting weak signals.

The current program is an extension of this, in which the individual p-n junctions can be separately addressed and biased by some charge transfer device, such as a CCD, bucket brigade, or single charge transfer device (CTD). This leads to the possibility of a programmable tapped delay line, variable delay devices, variable band pass filters, adapted filters, etc. This marriage between very high frequency surface wave devices and lower frequency charge transfer devices using MIS technology would open up tremendous new possibilities in signal processing. It has been pointed out, for example, by various people including Mr. Harper Whitehouse of NOSC, that such systems would be exceedingly valuable, for example, in applications to adaptive antennas.

The program at the moment is concerned with developing a suitable technology, so that one can have a zinc oxide piezoelectric layer which provides the acoustic surface wave on the same substrata as the charge transfer device. The problem seems well within the range of technology we now have in hand, although there will be considerable effort required in order to get the kind of properties that one wishes.

Unit 3 — <u>Research on Fiber Optic Interactions with Applications to High-Speed Signal Processing</u>

The objective of this program is to study new interactions in optical fibers, with a view to using such fibers for high-speed signal processing. That is, one would try to produce the equivalent of tapped delay lines (or possibly

nonlinear interactions) as one does in electromagnetic or acoustic lines, but with data rates and bandwidths many times greater than are available with these more conventional means.

The approach would be to use very long, single mode, optical fibers, taking advantage of the low attenuation of such fibers (one to two db per kilometer) for storing and processing very long signal trains. Even with the existing attenuation one can get storage times of many microseconds. Seventy-five microseconds, for example, would correspond to perhaps 15 to 30 db. With the use of optical amplifiers for recirculation of the signal, one can obviously do much better. Another project being conducted here under other sponsorship is concerned with developing suitable amplifiers for other applications and would be used in this project when available. However, even in the absence of an amplifier one can still get very interesting performance. A key component is a directional coupler suitable for single mode fibers, which can tap (or inject) a propagating signal in a fiber without breaking into the fiber. Such directional couplers do not exist and a principal portion of this effort currently involves various methods to devise (and test) such couplers.

Unit 4 — Nonlinear Interactions of Acoustic Waves with Domains in Ferroic Materials

The goal of this project is to study the nonlinear interaction of acoustic waves with domains in ferroic materials (ferromagnetic, ferroelectric and ferroelastic) materials, first to understand the physics involved and then to explore the possible use of such interactions for possible device applications.

The material under investigation is gadolinium molybdate, which is ferroelastic and ferroelectric as well as piezoelectric. The purpose of the initial experiment will be to try to produce motion of domain walls in a resonator made

of this material, by applying a suitable acoustic field. This will not only demonstrate a very interesting property (that is, motion of a domain wall by the acoustic field), but will also provide a measurement of the nonlinear elastic constants of the material, which is also important. This will be a first step towards understanding the properties of this very interesting material. Also, at a later date, we will try to see how these properties can be used in devices of various kinds. In addition to the experiment, there is theoretical work being done in trying to understand some of the elastic behavior of this material as a function of crystallographic direction.

Unit 5 — Measurement of Ultra Fast Physical Phenomena

This project is concerned with the experimental demonstration of a new method for measuring ultra fast physical and chemical phenomena, using a "tunable transient grating" approach. The technique will make possible measurements which normally would be done by subpicosecond pulse spectroscopy but without requiring ultra short laser pulses. The basic approach is to use a laser induced grating, produced by coherent interference between two continuous laser beams of slightly different frequencies. One produces in this way a moving grating of optical excitation (of the species being investigated) with velocity proportional to frequency difference. One probes this moving grating with a third laser beam, the power diffracted, as a function of the difference frequency of the excitation beams, provides information about lifetimes, diffusion of excited state, etc. Currently the requisite apparatus is being assembled.

Unit 6 — A VUV and Soft X-Ray Light Source

A tunable, high intensity monochromatic VUV has been developed in this laboratory under other auspices, with a wave length range around 500 to 600 angstroms. The method for producing this radiation can be extended to other atoms, so that one can foresee getting this kind of tunable source over a very wide range of short wave lengths. This project is concerned with the application of such sources to precision spectroscopy. The source we now have has been applied under JSEP to some specific spectroscopic measurements, which are important in themselves. But also some new ideas have been developed for general spectroscopic instruments, using these kinds of sources and these should provide a spectroscopic tool for an important range of frequencies which is not accessible at present.

JSEP Sponsored*

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UNIT 1

HIGH-T_c SUPERCONDUCTING WEAK-LINK JOSEPHSON JUNCTIONS AND CIRCUITS*

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A. Scientific Objectives

The underlying, long term objective of this program is to explore the feasibility of high-T_c and/or hard Josephson junction superconducting thin film circuits; to establish the relevant physics, fabrication procedures, and operating characteristics of such devices; and hopefully to lay the ground work for a superconducting integrated circuit technology based on these materials. This objective requires the development of practical high-T_c and/or hard Josephson junctions and also the passive circuit elements necessary for a complete circuit technology. Success in this program would lead to devices capable of operating at substantially higher temperatures (~ 10-15 K) and/or to more rugged circuits resistant to damage due to thermal cycling, handling, and hostile field environments.

Toward this general objective we have been attempting to develop high-T_c superconducting weak-link (i.e. non-tunneling) Josephson junctions and by necessity thin-film deposition, microlithography, and processing technologies suitable for high-T_c and/or hard superconducting materials. We have been concentrating our efforts on the A15-type superconductors, specifically Nb_3Sn ($T_c \approx 18K$) with related work on elemental $Nb(T_c = 9K)$ in order to more easily test some of our fabrication techniques.

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*Superconducting Electronics with High T_c Materials

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B. Approach

From the theoretical point of view when considering high-T_c superconducting materials the most attractive type of weak-link Josephson junctions appears to be SNS (superconductor/normal metal/superconductor) or SSemiS (superconductor/semiconductor/superconductor) bridges. In this program we are focusing on SNS bridges. These bridges are like the usual microbridges but where the bridge region itself is a normal metal while the banks are superconductors. The rationale for such devices is that by making the bridge from a normal metal (e.g. Cu, Au or Ag) one can circumvent the extremely small (< 100 Å) bridge dimensions theoretically required in a totally superconducting high-T_c bridge to obtain ideal Josephson behavior. In such SNS bridges the dimensions need only be submicron and ideal Josephson behavior should be available over the entire temperature range $0 < T < T_c$.

To achieve such structures in practice we have been using electron-beam evaporation to make suitable thin film bilayers (e.g. Nb_3Sn or Nb on top of Cu) out of which the desired submicron planar SNS (e.g. $Nb_3Sn/Cu/Nb_3Sn$) bridges are formed by projection photolithography and suitable differential etching procedures. The fabrication procedures are then appropriately modified in light of the observed electrical properties of the junctions. More specifically the problem is to fabricate a short ($\leq$ 1 μm) normal metal bridge connecting two superconducting banks while insuring good contact at the S/N interfaces and not degrading the superconductivity (e.g. reducing T_c) of the banks through damage in the fabrication process. At the same time we have been developing theoretical models for such devices based on the Usadel and Time-Dependent-Ginzburg-Landau Theories of superconductivity.

C. Progress

In the earlier phases of this project we explored various techniques for actually forming the desired submicron bridge structures. The necessary projection photolithography techniques were mastered and various etching techniques explored. In summary these studies demonstrated the feasibility of the planar SNS concept and indicated that devices with important practical characteristics could be fabricated in principle from the high-T_c hard superconductors in a manner compatible with integrated processing. The procedures used were not ideal, however. Specifically we found that wet chemical etching and ion milling were not entirely suitable for processing such SNS bridges. Wet etching is simply too erratic and unreliable for submicron structures, and ion milling, while giving excellent resolution, damages the superconducting materials of interest degrading their T_c and other superconducting properties. Thus while SNS bridges operating from $0 < T < T_c$ were successfully made, their electrical properties were inferior to those expected ideally from theory. A summary of these results along with a thorough discussion of the optimal selection of materials and the anticipated practical parameters of such junctions has been published during the last year.[1.1]

To overcome the problems uncovered in this earlier work we have been exploring alternative processing techniques. A remarkable result along these lines has been the development of a refractory lift-off process to materials which must be deposited at high substrate temperatures where ordinary photo-resist is unusuable. This adds a new degree of freedom in device processing of high-T_c superconducting materials which has been heretofore impossible. The process may have

applications in other areas of technology as well where there is a need to pattern refractory materials. A patent disclosure has been filed. Also an account of this work was published during the last year,[1.2] and we are presently considering ways of adapting it to our processing needs. At the same time we have been exploring the application of plasma (or reactive ion) etching to superconducting device fabrication. It affords delicate material removal, selective etching, and high resolution. Our preliminary results were very encouraging and we have now consolidated our projection photolithography and plasma etching facilities in a new clean room.

With these new improvements we now can routinely make submicron SNS structures with very good spatial definition and material discrimination. Unfortunately the electrical properties of the resultant structures still remain below the ideal expected. With all other known crucial processing variables apparently under control, the problem appears to be associated with an insufficiently clean S/N interface between the superconducting and normal materials where they join in the banks of the bridge. We are further directed to this conclusion by recent results reported by the Cornell group[1.3] on similar SNS planar bridges (formed with low T_c materials) for which great care in obtaining a clean interface was required but did ultimately lead to nearly theoretical performance. In light of these results we are now focusing our attention on these interface problems. Happily this is the area where we have least exercised our available degrees of freedom in the past.

To improve the S/N interface in our junctions it should be sufficient to improve the interface in the initial S/N bilayer from

which the bridge is subsequently fabricated. To this end we plan to attempt deposition procedures designed to minimize exposure of the lower surface to the vacuum environment subsequent to deposition of the upper layer. If required we will clean the lower surface (chosen to be the damage insensitive normal material) with the ion gun system which we have on order and which is capable of producing beams of both reactive and nonreactive ions of variable energy. Available soon also will be a scanning SIMS surface chemical analysis probe that will provide in-situ surface diagnostic information. It is expected that both of these systems will be installed and operating in our e-beam evaporator within 6-12 months.

Along with the above work we are continuing our modeling studies. The necessary partial differential equations have been programmed on a digital computer and now provides results routinely. With this program we should be able to test recent theoretical conjectures regarding the hysteretic behavior observed in some SNS bridges.[1.4]

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UNIT 2

ACOUSTIC SURFACE WAVE SCANNING OF OPTICAL IMAGES*

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(J. Green)

A. Introduction

Our aim at the present time is to work towards new types of acoustic surface wave devices in which there is interaction with a semiconductor substrate. All the device designs in which we are interested are based on the ZnO on Si configuration where a piezoelectric material is laid down on a silicon substrate so that the interaction may be obtained between the electric fields of an acoustic surface wave and the silicon.

We have two types of devices in mind:

1. an optical holographic system to be used for the reconstruction of optical images by interaction of acoustic surface waves in the silicon substrate; and
2. a programmable active delay line in which signals can be read into the device by means of a charge transfer device (CTD) on the silicon substrate underneath or beside the ZnO layer. Then having formed a programmable filter in this way, we would be able to use it for a wide variety of signal processing functions and in particular for adaptive and inverse filtering.

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*Proposed as "Acoustic Surface Wave Scanning of Optical Images II" in September, 1978.

B. Progress to Date

(1) Combined CTD and SAW Devices

We fastened our sights on this latter concept rather than the first concept during the year because our initial thinking tends to make us believe that the optical imaging system is an extremely difficult one to realize. Furthermore, it requires far too much new equipment and technology to warrant support at present rates on the Joint Services Program. More positively, because we have made considerable progress with our adaptive filtering and inverse filtering concepts, we feel that the signal processing aspect of this work is vitally important and will lead to a whole new generation of devices suitable for spread spectrum communication, radar processing, acoustic imaging, sonar, and other important applications.

The basic idea here is to construct an adaptable monolithic SAW filter which can be programmed from an external source. To do this, we intend to combine the features of the SAW and charge transfer device (CTD) on one silicon substrate and therefore avoid the pitfalls of hybrid technology which limit the number of effective taps which can be employed. The basic principles on which this device operates follow from our earlier experience on the storage correlator. Thus, in order to understand these concepts, it is worthwhile to reiterate in a simple form the concepts of the storage correlator.

The basic storage correlator, illustrated in Fig. 1, employs a piezoelectric ZnO layer deposited on Si . Interdigital transducers are used at each end of the device to inject or receive acoustic surface wave signals. In the central region, a row of p-n diodes is

fabricated in the silicon underneath the acoustic beam path and a metal electrode, called the top plate, is deposited on top of the zinc oxide film.

In order to understand the operation of this device, consider what happens when a short pulse of voltage V is applied to the top plate. The pulse "turns on" each diode so that the capacity between the top plate and an individual diode becomes charged to a potential close to V. After the pulse is turned off, the capacity remains charged; clearly then, the device can store an analog signal. If at the same time an acoustic surface wave signal is passing under the plate when the diode is turned on, the signal stored in the capacitor consists of the sum of the acoustic surface wave signal and the applied pulse. A spatial pattern of charge corresponding to the surface wave signal is stored along the length of the device. At a later time, a further "reading" pulse applied to the "top plate" turns on the diodes once more, but the potential at which they turn on depends on the signal stored in the capacitors. Thus, a spatially varying signal is excited along the length of the device which, in turn, excites acoustic surface waves which can be received on either interdigital transducer. If a more general form of reading signal is applied, the correlation of this signal with the original signal read into the device is obtained as an output from one transducer, and the convolution of the two signals is obtained from the other transducer.

The device itself has been operated in several different modes, but basically it functions as a highly flexible signal processing device which correlates signals either read into it at the same time or read into it at different times.

At the present time, the silicon technology for the acoustic surface wave storage correlator is carried out in the Integrated Circuit Laboratory, while the zinc oxide deposition is carried out in the Ginzton Laboratory. Obviously, the work could not be done without the use of such IC technology.

The next step along the way is to employ far more sophisticated semiconductor techniques than just the construction of simple diodes. These involve processing high-frequency signals of the type to which surface wave devices are best adapted, but controlling the processing with relative low-frequency analog or digital signals. Thus, the aim is to vary an acoustic surface wave filter at will, reading in the necessary tapping configuration slowly, either in the form of an analog or digital code. It becomes attractive, therefore, to marry acoustic surface wave concepts with such concepts as that of the charge coupled device, the bucket brigade device, or the single transfer device, i.e., capacitive delay line, which are best suited for low-frequency operation. It also is of interest to consider such configurations as systems for reading in and processing a signal at high speed in an SAW device but reading out the processed signal or correlation output at low speeds through the CTD device.

At the present time, photo-sensitive devices have been developed which can read out the charge produced by light incident on a row of diodes from an illuminating source, such as one line of a TV image. Thus, the basic devices exist which can switch from an input-output line to any one of a row of diodes. There is, therefore, the possibility of depositing zinc oxide on this row of diodes, with an interdigital transducers at each end of the zinc oxide layer. This makes

it possible to construct a highly flexible acoustic surface wave storage correlator, for now each diode can be addressed externally.

We are constructing such a system using a commercial single transfer device (STD) made by Reticon which as a circuit is shown in simplified form in Fig. 2. This device (RL 512 S) is a solid state line scanner in which a series of FET switches are used to connect individual diodes to an input-output line. These switches are ddressed one after the other by a controlling signal inserted into a tapped shift register with one tap per switch. Thus with the Reticon device we possess the capability of switching to any one of 512 diodes and ultimately to any one of a row of 1024 diodes. The beauty of using this device lies in the fact that in order to convert it to an adaptable SAW filter, we need only deposit a zinc oxide layer with a metal film laid on top of it, and associated surface wave transducers, on top of the diode array. Thus, we are able to read a signal into (or out of) the diodes at the surface wave frequency (136 MHz) but also address the diodes slowly at the frequency of the CTD multiplexor (less than 2 MHz).

As one simple example, we can read in a coded signal through the STD into the diodes. This forms a set of taps with variable weighting on the acoustic surface wave delay line. Therefore, if a signal is read into the acoustic surface wave delay line and read out of the top plate on the high-frequency terminal, the device acts as a programmable tapped delay line. Thus, we should be able to make programmable filters, variable delay devices, etc. by reading a low-frequency analog signal into the device. As this low-frequency analog signal can in turn be controlled from a shift register or RAM through a D-to-A converter, we now have the possibility of constructing a range of coded surface wave devices whose codes are obtainable from a memory.

A second possibility is to read in a high frequency signal to the device and store it in the normal manner of the storage correlator, then read out the stored charge, i.e., the signal at a relatively low frequency by the STD system. This makes it possible to obtain low-frequency signals identical in form to the original high-frequency signals read into the device, i.e., with the same time-bandwidth product. These signals can then be inserted directly into a computer or into any other code recognition device which operates at relatively low frequencies. By operating this system in reverse, an analog signal of arbitrary form can be obtained from a microprocessor and then read out as a high-frequency signal with the same time-bandwidth product. Normally it is extremely difficult to accurately produce complicated high-frequency waveforms such as nonlinear FM chirps. This process would make it simple.

There are numerous other possibilities. One example is a programmable delay line whose delay can be varied during the time the high-frequency signal is passing through the delay line; a device much needed for acoustic image processing. Other examples are variable bandpass filters, adaptive filters, and Wiener filters. A particularly important example in which we are very interested is to use the device as a normal storage correlator to correlate two input signals. Now, however, because it is possible to read out the correlation peak through the STD, we can obtain correlation signals at as slow a rate as we wish. Thus, we would expect to be able not only to read out correlation signals at relatively slow and convenient rates but also to perform further integration at extremely slow speeds, so as to obtain the equivalent of extremely large time-bandwidth products in the signal processing.

We believe that these concepts are merely the first of a wide range of devices which could be constructed with entirely new configurations and systems architecture if the necessary LSI and VLSI silicon technology were available. We have described here, for instance, only a device controlled from a shift register input; a still more flexible device could be made if the control were directly made from a RAM input rather than the shift register. Yet other possibilities arise by using amplifiers in the acoustic analog system rather than passive diodes. Thus, with a sophisticated technology available, a new signal technique can be devised to carry out analog or digital signal processing in real time at relatively high frequencies (in the UHF range).

One difficulty in using the Reticon device occurs in our ability to deposit high-quality zinc oxide over the diode array. Although our zinc oxide technology has progressed to the point where we can reliably deposit high-quality zinc oxide over thermally grown silicon dioxide, we have experienced some difficulty in performing the zinc oxide deposition on top of the chemical vapor deposited (CVD) silicon dioxide as is found over the diode array on the Reticon device. This is due to the more irregular structure of the CVD silicon dioxide as compared to the thermally grown silicon dioxide. In order to surmount this problem, we are presently engaged in depositing our own sputtered silicon dioxide layer on top of Reticon's CVD layer. It is our hope that the sputtered silicon dioxide layer will be of sufficiently high quality so as to allow us to proceed with the deposition of a high-quality zinc oxide layer on top of this silicon dioxide.

If necessary, we can obtain a CTD from the manufacturer without the poor-quality CVD silicon dioxide present, although this would be considerably more difficult. Thus, we prefer to work in the manner we have described, although our results are not critically dependent on this approach. Eventually, when we have eliminated this particular technological difficulty, the intention is to work with a thick layer of SiO_2, of the order of 8 microns thick, with an input frequency of 165 MHz, a layer approximately one half wavelength thick. In this case, the coupling coefficient of the waves will be increased, and the transducers could be operated over a relatively broadband, comparable to that of lithium niobate, device. We have been carrying out theory on various types of propagating modes in such thick layers. We will decide after initial tests whether to use a Sezawa mode in which the interdigital transducer is placed on top of the zinc oxide layer or the more difficult to use but more conventional perturbed Rayleigh mode with the interdigital transducer between the zinc oxide and the SiO_2.

It is clear that if we succeeed in demonstrating this monolithic device, we will have arrived at a new generation of acoustic surface wave devices married to MIS devices. The point of the exercise is basically to demonstrate that we can obtain the advantages of both silicon MIS technology and the powerful signal processing capabilities of acoustic surface wave devices and combine the best features of both.

(2) Waveguide Devices

We initially felt that a basic building block for both the optical system and the programmable delay line would be a narrow waveguide

type acoustic surface wave device, so as to be able to get the packing density high, and the efficiency of read-in and read-out high because of the lower capacities involved with the use of a narrow acoustic beam. We have therefore spent considerable effort on this concept, both because of these needs and because of its own merit and intrinsic interest. The basic idea was to use a layer of ZnO on Si etched to a width of three wavelengths (100 μm) which forms the waveguide. We then employed narrow interdigital transducers of approximately the same width to transmit and receive the acoustic waves. We designed high-impedance transformers matched to these transducers, although initially much of the work was carried out without use of such transformers so as to test the concept. We found that we were able to obtain reasonable waveguiding and reasonable transduction efficiency. Although the initial results were encouraging, however, we had a great deal of difficulty with etching the ZnO with good reproducibility on such small structures so as to make an efficient device. Despite these difficulties, we were able to construct a waveguide convolver with -60 dbm efficiency, which compares to a similar full width convolver of -70 dbm efficiency. This is because of the high power density obtained in the narrow guide.

Due to the difficulty of consistently etching the zinc oxide with good results, we instead focused our efforts toward a waveguiding structure that used the properties of a gold film deposited over the zinc oxide in the region of the desired acoustic beam. Since the surface wave velocity is slightly lowered in the presence of the gold film, the surface wave tends to propagate only in the region defined

by the gold film; therefore the waveguiding effect is achieved. The results obtained from a waveguided convolver of this type have been extremely encouraging and showed a convolution efficiency of -45 dBm ; 10 dB better than in any previous ZnO convolver, and comparing favorably with our best airgap convolvers (-42 dBm) and best full-width ZnO on Si convolvers (-55 dBm). A paper has been submitted on this device to the 1979 IEEE Ultrasonics Symposium.

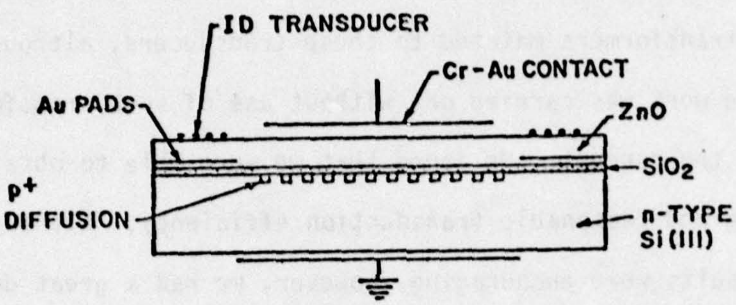

Fig. 1. Schematic of the zinc-oxide-on-silicon monolithic storage correlator

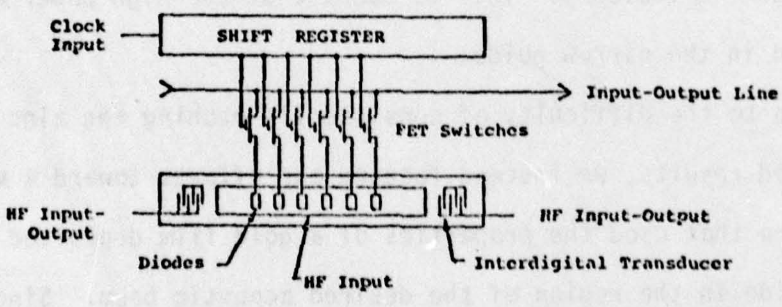

Fig. 2. A schematic of the acoustic surface wave-STD multiplexer configuration

PAPERS PRESENTED -- June 1, 1978 - May 31, 1979

1. Signal Processing Based on Combined Charge Coupled Devices and Surface Acoustic Wave Devices. P. M. Grant - presented at IEEE International Symposium on Circuits and Systems, May, 1978.

2. Highly Efficient Transducer Arrays Useful in Nondestructive Testing Applications. C. S. DeSilets, A. Selfridge, and G. S. Kino - Ultrasonics Symposium, September, 1978.

Unit 3

FIBER OPTIC SIGNAL PROCESSING

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A. Introduction

Systems for high speed signal processing using optical fibers are being studied under this project. The first step involves the development of addressable memory elements in the form of tapped optical delay lines, and the development of key fiber optic components required for these delay lines.

The data rates and sample sizes in such systems as DSP, CCD, or SAW, for signal processing operations of convolution, correlation, Fourier transformation and the various processing and filtering functions which derive from them, are much lower than are potentially achievable with optical systems. Modern optical fibers have extremely attractive properties for use in delay lines for these purposes. They occupy very small volume while having the potential for attaining the desired signal processing performance.

We have demonstrated basic operation of a fiber optic recirculating delay line. We have made progress toward the development of the principle fiber components, namely integrated directional couplers and optical amplifiers, which will be needed to extend the capabilities of such delay lines into ranges of speed and data volume of interest for future applications.

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B. Signal Processing Systems

1. Recirculating Delay Lines

The first system being studied is a recirculating memory store consisting of a closed loop delay line containing a tap which allows optical signals to be introduced into the loop and to be nondestructively sampled as they circulate around the loop. Recirculating delay lines of this kind are well known at microwave frequencies for temporarily storing and recalling signals.[1] These same signals could be modulated onto optical carriers and stored in fiber optic recirculating systems, taking advantage of increased bandwidth and storage time and decreased size. Banks of recirculating delay lines can be combined to build up volatile memories of large capacity for signal processing, in which individual bits are stored in separate delay lines forming high speed word-addressable systems. Such systems have been demonstrated using acoustic delay lines,[2] and could be implemented at higher speed in fiber optic recirculating delay lines. A form of matrix processing using wraparound closed-loop acoustic delay lines demonstrated previously under a JSEP project is an example of novel applications of recirculating memory systems.[3]

A coil of optical fiber waveguide constitutes a delay line having excellent basic properties, including substantial time delay (5 microseconds per kilometer), very low propagation loss (order of 0.1 dB per microsecond), and very large bandwidth.

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[1] L. A. Coldren and H. J. Shaw, Proc. IEEE 64, 5, 598-609 (May 1976).

[2] E. K. Sittig and J. F. Smits, Bell System Technical Journal, 659 (March 1969).

[3] C. M. Fortunko and H. J. Shaw, Trans. IEEE SU-21, 1, 40 (January 1974).

We are presently working with a single mode fiber delay line of 3 microsecond delay in the form of a 600 meter length of fiber wound into a coil. We are experimenting with the problem of recirculating optical pulses in this delay line. An optical pulse introduced at one end and extracted at the opposite end is repeatedly reintroduced into the input end.

The signal injection, reinjection and sampling functions are performed by a hybrid directional coupler developed under the JSEP program. It consists of a glass prism with two parallel, optically polished surfaces, one of which is metallized to form an internal reflecting surface. Introducing light through the second surface, and utilizing total reflection from the first surface and partial reflection from the second surface, the device performs as two back-to-back directional couplers. The coupling coefficient is variable from - 10 dB to - 20 dB by rotating the polarization of the light. This coupler is used to close the fiber optic loop upon itself, and to introduce and sample pulses in the loop with the above coupling coefficient.

We have observed five recirculations around the loop, for a total signal storage time of 15 microseconds, using optical pulses of two microseconds duration. This is the first signal recirculation in fiber delay lines of which we are aware.

The number of recirculations observable is presently limited by saturation of the photodetector by direct (stray-light) coupling of the input laser and the photodetector, i.e., the classical leakage pulse present in varying degrees in all types of delay lines. An optical

switch, for gating out only the desired echo, is being installed and is expected to provide a longer observed output echo train.

The purpose of the above work was to obtain experience with the characteristics and problems of pulse recirculation in delay lines of single-mode fiber, which are the type of greatest eventual interest because of their bandwidth capability. We have found that hybrid coupling systems, in which the recirculating optical signals are extracted from the fiber and passed back into the fiber by means of lens, mirror and prism systems, are extremely difficult to adjust and maintain, and are the limiting factor in the delay line performance. Basically, the problems of coupling the external signals into and out of the loop, on the one hand, and of recirculating these signals on the other hand, are inter-locking operations, each having a second order effect upon the other, so that simple iterative adjustments to align the system are not satisfactory. For this reason, as well as for obvious reasons of ruggedness and size, integrated fiber directional couplers are considered essential to the future of these systems, and are under development as described later. The fiber used to form the present delay line was procured under an AFOSR program on inertial rotation sensing, and is being shared with the JSEP program as both programs are concerned with pulse recirculation, although with different objectives and different processing.

2. Transversal Filters

A multi-tapped delay line, or transversal filter, consists of a delay line containing a multiciplicity of taps located along its length

which can nondestructively sample signals which are propagated along the delay line.[1,4] The nature of the signal processing is determined by the distribution of the taps, the weightings of the individual taps, and the way in which the tap outputs are combined.

A novel type of tap for a fiber optic delay line, involving a nonlinear interaction in the fiber, is being studied. Briefly, a wave propagating in one direction in a fiber can be tapped by sending another wave in the opposite direction, provided the fiber possesses a second-order nonlinearity. Energy at the sum frequency of the two waves will radiate freely from the fiber, where it can be collected by a detector. Furthermore, the second wave (reference wave) can be modulated with a desired signal, and the radiated output will be the integral of the product of the input signal and the reference signal, allowing convolution and correlation operations to be performed. We had originally intended to carry out an early test of this principle using lengths of single-crystal lithium niobate fibers as the test vehicle. Unfortunately, such fibers have not been available to us during the past year. We are setting up to produce single crystal fibers here under an AFAL program in the laboratory, and fibers from that program are expected to be available to the JSEP project during the coming year, for use as a vehicle to test the basic mechanism. In the meatime, we are planning to carry out such a test jointly with an industrial laboratory using an alternate vehicle.

C. Directional Couplers

As stated above, the most crucial immediate need is for integrated fiber directional couplers. Under the JSEP program we are developing

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[4] Gordon S. Kino and John Shaw, Scientific American 227, 4, 50-68 (October 1972).

couplers which are expected to be cornerstone items for both the signal processing work under this program and the inertial rotation sensing work under the AFOSR program. In the directional coupler field there is a small history of initial attempts, including some encouraging preliminary results. Couplers which people have considered in recent years cover a number of general types. These include the following, some of which involve surgery on the original fibers, and some of which do not. With few exceptions, they have been applied only to multimode fibers.

1. Couplers based on beam splitters, prisms or angular injection. Both hybrid and integrated versions have been proposed and/or tried in preliminary experimental models.

2. Mechanical grating couplers, involving sinusoidal distortion of fibers which then exchange radiation with surrounding media, and whose coupling can be varied by adjusting the depth of the mechanical perturbations.

3. Tapered couplers in which narrowed sections are produced in a pair of fibers (e.g., by drawing down) having reduced cladding thickness and which exchange energy by means of radiation modes in a mutual surrounding guiding medium.

4. Parallel or twisted fiber couplers having reduced cladding thickness (i.e., by mechanical lapping, fusing together, or chemical etching) which transfer energy by means of overlapping evanescent modes.

5. Planar couplers involving coupling (e.g., butt coupling) of fibers to parallel diffused strip waveguides (either multimode or single mode) on planar integrated optics substrates, with or without electro-optic control of coupling.

6. Acousto-optic couplers, an approach to switchable directional couplers which was original with us, would involve the use of an acoustic wave to form dynamic gratings on fibers. High frequency ultrasonic waves can be excited on fibers, and can propagate along the fibers. Energy transfer mechanisms which can be produced by mechanical perturbations could likewise be produced by the acoustic perturbations caused by these waves. Under the JSEP program, we have carried out a preliminary theoretical study of mode diffusion and radiation in multimode fibers under the influence of colinear acoustic propagating waves in the fiber. This work, which was completed prior to the reporting period, indicates that reasonable parameters are involved. Such couplers would be completely noninvasive. The acoustic transducer could in principle be deposited on the outer periphery of the fiber cladding. With the acoustic wave turned off, the coupler would have no effect whatever on the wave propagating on the fiber. With the acoustic wave switched on, signals could be read out of or into the fiber with an electronically adjustable coupling coefficient. No further work was done on this coupler during the past year, because of time limitations. It is considered to be an important item for future work.

The first form of coupler undertaken in the present program is a parallel coupler. Two sections of fiber are brought into side-by-side contact for a short distance, where the coupling is to take place. To achieve coupling in this region, part of the cladding surrounding the fiber cores must be removed. This allows energy from waves propagating in the cores to extend outside the fibers, in the form of evanescent fields which can provide coupling between the two fibers. For single

mode fibers this is a difficult problem, because of the small diameter (approximately 4 microns) of the core. Our present approach to core removal is mechanical lapping and polishing. Each fiber is permanently bonded into a tapered groove in the flat surface of a glass block in such a way that, using a standard flat lapping wheel, the desired amount of material (approximately the entire cladding) can be removed from one side of the fiber. Bringing two such assemblies together at their lapped surfaces brings the two fiber cores into sufficiently close proximity to achieve coupling.

The principal problem encountered is breaking of the fiber cores into multiple disconnected segments. We have carried out a series of experiments which have overcome this problem, have shown that we have the necessary dimensional accuracy in the lapping process, and have succeeded in producing coupled light from fiber to fiber. We are now completing work on more elaborate models, on which the full set of directional coupler properties can be determined.

A second approach to directional couplers under the project is a twisted fiber coupler. It also involves mechanical lapping, but with a novel approach to the lapping operation in which each fiber laps the other, just in the region where coupling is desired. This process has the advantage of removing cladding material from only a portion of the fiber circumference, leaving maximum strength in the fibers, for mechanically rugged couplers having minimum overall dimensions. A bank of six lapping units has been constructed and is in operation, allowing simultaneous lapping of six fiber pairs using different parameters. At this date the lapping appears successful under microscope inspection, and optical coupling measurements will follow in the near future.

A third approach to directional couplers presently being investigated is a parallel coupler using chemical etching to remove cladding material from the fibers in the coupling region. Here our approach differs from other etching procedures which have been reported.[5] Instead of etching the cladding from the entire circumference of the fibers, we arrange to etch only half of the circumference again to conserve strength. We have carried out etching experiments, and find that when the entire cladding circumference is etched one is left with fiber sections having low mechanical integrity, making adjustment, handling and potting quite difficult. Another feature of this design is a novel means for electronically controlling the spacing between the two fibers. This control will be used during the etching process, and also has potential for use in the final coupler for electronically varying the coupling coefficient. Experiments on this approach will be undertaken in the coming period.

D. Fiber Amplifiers

Although optical fibers have lower propagation loss than competing delay line media, a delay time of 1 millisecond in a passive fiber is accompanied by a propagation loss of 100 dB, which is excessive for a delay line of high dynamic range. The question of reducing this loss by means of amplifiers was studied earlier under the JSEP program. It was shown that laser amplifiers in fiber format, using single-crystal Nd:YAG fibers with lengths in the range of centimeters to tens of centimeters, appear feasible. Means for distributed pumping of the fiber,

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[5] S. K. Sheem and T. G. Giallorenzi, Optics Letters 4, 1, 29 (Jan. 1979).

leaving the fiber ends free for insertion into the signal fiber path, were devised. The optimum amplifier gain is of the order of 5 dB, and the optimum spacing along the delay line is the order of 50 microseconds. In the case of closed loop recirculating delay lines as discussed above, a single amplifier would be employed, producing optimum signal-to-noise ratio in a closed fiber loop of some 50 microseconds delay. During the past year arrangements have been made for an AFAL contract to develop such amplifiers, with application to rotation sensing under the AFOSR program, and to signal processing under the JSEP Program.

Unit 4

NONLINEAR INTERACTIONS OF ACOUSTIC WAVES WITH DOMAINS IN FERROIC MATERIALS

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A. Introduction

The goal of this project is to study the nonlinear interaction of acoustic waves with domain walls in ferroic (ferromagnetic, ferroelectric and ferroelastic) materials with a view, first of all, of achieving a better understanding of the basic physics involved and, then, of evaluating the potential of such interactions for new device applications.

Any domain wall, whatever its nature, exhibits a relatively abrupt change in material properties from one side of the wall to the other, resulting from the rearrangement of the microscopic structure of the solid between one domain and the next. Such a discontinuity in material properties constitutes, in a sense, the fundamental structural element in any boundary value problem involving wave propagation and is therefore the basic "building block" for a large variety of wave interaction devices. Material discontinuities arising from domain walls have the particularity of being mobile - that is, they can be displaced by an applied magnetic field in a ferromagnetic material, by an electric field in a ferroelectric material, and by an elastic field in a ferroelastic material - and, for this reason, they offer possibilities for

realizing wave interaction devices whose structure can be switched electronically at a more or less rapid rate. In some cases, also, a "latching" feature exists. The domain structure remains in its new configuration after removal of the switching field. Possible device applications of this phenomenon, involving arrays of material discontinuities realized by various domain wall structures, include diffraction and phase matching gratings, directional couplers, filters and memory stores.

In this project we are especially concerned with nonlinear interactions between acoustic waves and domain walls. In this category of phenomena we include:

(1) The effect of the presence of a domain wall or walls on the nonlinear properties of the medium. By this we mean changes in the nonlinear properties within and near the domain wall, particularly in the vicinity of a transition temperature.

(2) The influence of domain wall structure on acoustic wave parametric processes and harmonic generation. It is now well known in many areas of physics that nonlinear wave interactions can be enhanced by introducing a periodicity of the medium to "phase match" the various waves taking part in the process. Bragg scattering is an example of phase matching in the linear regime.

(3) The displacement of a domain wall under the action of "static" forces generated by "rectification" of an acoustic wave (i.e., generation of static magnetic, electric, or elastic fields as a result of the nonlinearity of the medium).

Primary emphasis is placed on Item 3 above because of its potential for future applications. For example, if such a phenomenon can be shown to

exist, one may envisage "locking" an array of domain walls onto a spatially periodic zero frequency field generated by rectification of a standing acoustic wave and then tuning the period of the array by varying the acoustic frequency. Clearly, a good basic understanding of the nonlinear properties of the material (Item 1) is essential to a study of this phenomenon, and parametric interactions (Item 2) constitute one of the most commonly used techniques for measuring such properties.

Our work is focused primarily on one material, gadolinium molybdate (GMO), because of its remarkable combination of properties and its availability. It is both ferroelastic and ferroelectric, as well as being fairly strongly piezoelectric, and has excellent acoustic and optical qualities. The domain walls, which are boundaries between regions with different degrees of spontaneous strain move easily under the action of rather small mechanical and electrical forces, and the domain structure is easily observed by means of a strong electrooptic effect. It has also been shown that ferroeleastic stripe domain arrays can be realized in GMO. The sole disadvantage of this material is that it is rather brittle and difficult to work mechanically. At the present time the nonlinear elastic constants are unknown. However, as was noted in the original proposal, by using a conservative estimate for the values of the nonlinear constants and the measured threshold for domain wall motion under the action of an applied stress one finds that wall displacement should be achievable by rectification of a resonant acoustic wave at a rather modest intensity level. Since GMO is basically unstable mechanically - the spontaneous strain "flips" easily under the action of a rather small applied stress - it is

expected that the nonlinear elastic constants will be larger than is usually the case. Consequently, the acoustic intensity required to produce domain wall motion may be lower than anticipated. Our current efforts are directed toward a direct experimental test of this prediction and toward measurement of the nonlinear elastic constants of GMO.

B. Progress

During the past year our experimental effort has been directed toward the design, fabrication and testing of a face shear resonator for performing the domain wall displacement experiment described in the introduction. This resonator is a plate of GMO cut with the domain wall oriented normal to the face and parallel to an edge. In this cut a shear vibration in the plane of the plate with polarization parallel to the domain wall (the appropriate orientation for nonlinear interaction with the wall) can be excited through the inherent piezoelectricity of the plate by means of an electric field applied normal to the plate. In the initial stages of this design project we considered using a PZT transducer bonded to the GMO plate as a means of exciting the desired vibration. However, this was found to pose problems with respect to achieving a satisfactory Q - a Q of the order of 10,000 is required to perform the experiment at a reasonable power level - and our experiments showed that satisfactory coupling and Q could be achieved by using the internal piezoelectricity of the GMO.

In the final design the resonator operates in a half-wavelength face shear mode at a few hundred KHz. The dimensions of these resonators can be determined approximately from theoretical considerations, but it is very difficult to properly account for the correct edge conditions at the boundaries and for anisotropy of the crystal.

As a consequence, the final fine tuning must be performed by experimental cut-and-try. Clean resonances with Q's in excess of 10,000 were achieved in this way, using noncontacting electrodes. However, use of such noncontacting electrodes does not permit domain wall motion. Because GMO is strongly ferroelectric as well as ferroelastic, domain wall motion requires simultaneous switching of strain and electrical polarization, and it cannot take place readily without some provision for surface charge compensation. It is therefore necessary to short circuit the two faces of the crystal, which requires deposition of electrodes on the surface. The technology of producing such electroded resonators, with high Q and edges free of cracks and chips that tend to mechanically lock the domain walls, has proved to be difficult and has not yet been mastered. We have realized all the necessary characteristics (high Q, good coupling, easy domain motion) individually but have not yet found the desired sequence of fabrication steps needed to obtain a resonator satisfying all the necessary conditions at the same time.

In the area of theory we have been studying nonlinear elastic phenomena, particularly the third order elastic constants of this structure for various coordinate orientations, the analysis of nonlinear acoustic wave propagation and rectification in nonlinear materials, and various possible methods for using harmonic generation and parametric excitation as techniques for measuring the nonlinear elastic constants. With respect to these activities we are in contact with Professor Breazeale at the University of Tennessee and with French research groups active in the areas of ferroelasticity and nonlinear wave propagation.

Another feature of GMO being investigated theoretically is the analysis of strip domain structure and the influence of deposited films on these domains. We have developed a theory that differs from that of A. Kumada and appears to overcome some of the difficulties in their theory. However, certain problems still remain and we are continuing to pursue the matter.

Although our progress during the year has been slowed by the problems of mastering a rather difficult technology we have realized in GMO a type of acoustic resonator not previously reported in the literature - half-wavelength face shear operation in the several hundred KHz region - and have shown that such resonators are capable of having high Q.

Also we have been asked to submit a paper dealing with our work on acoustic wave interactions with domain walls at the American Ceramics Society Conference in September 1979.

Unit 5

MEASUREMENTS OF ULTRAFAST PHYSICAL PHENOMENA

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I. INTRODUCTION

The general objective of this group has been the measurement of ultrafast physical, chemical and biological processes using laser methods — an area which has come to be known as picosecond spectroscopy. The particular objective of this project is to demonstrate and make use of a novel technique we recently proposed[1] which should permit the measurement of subpicosecond physical phenomena using a tunable laser-induced grating method.

Over the past few years our group has successfully measured several ultrafast processes (partially under JSEP support) using picosecond laser pulses in a transient laser-induced grating technique.[2-7] In this technique two picosecond pulses from the same laser arrive at an experimental sample at the same time, but from two different directions, creating a transient interference pattern and producing a transient hologram or grating of excited

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[5.1] A. E. Siegman, "Proposed Measurement of Subpicosecond Excited-State Dynamics Using a Tunable-Laser-Induced Grating," Appl. Phys. Letters 30, 21-23 (15 January 1977).

[5.2] D. W. Phillion, D. J. Kuizenga, and A. E. Siegman, "Rotational Diffusion and Triplet State Processes in Dye Laser Solutions," J. Chem. Phys. 61, 3828 (1 November 1974).

states in the sample. The diffraction of a separate variable-delay probing pulse by this grating is then measured as a function of the delay between excitation and probe pulses, by observing the diffracted signal intensity averaged over many repeated pulses at each delay value. By observing the diffracted intensity versus delay time in this manner, one can measure the build-up and/or decay of the photo-excited states that form the grating, with a time resolution approximately equal to the laser pulsewidth. We have used this method to measure both fast relaxation times and orientational rotation times (10^{-8} to 10^{-11} sec) in organic dye molecules,[2,3] and also fast transport or diffusion processes of excited electronic states in organic molecular crystals.[4,5] Very interesting microwave acoustooptic effects have also been observed.[6]

Many important physical processes have characteristic times in the sub-picosecond range. The tunable laser-induced grating technique being developed under this project[1] is similar in some ways to the pulsed grating technique described above, but does not require the use of ultrashort pulses, and yet can have time resolution in the femtosecond range. In this technique the excitation beams are cw (or long-pulse) lasers which are tunable so as to have an adjustable frequency difference f_d between them. This frequency difference may be in the 0.1 - 10 cm^{-1} range. These two beams then produce a moving interference pattern, whose fringes sweep through the sample at a

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[5.3] Donald W. Phillion, Dirk J. Kuizenga, and A. E. Siegman, "Subnanosecond Relaxation Time Measurements Using a Transient Induced Grating Method," Appl. Phys. Letters 27, 85 (15 July 1975).

[5.4] D. D. Dlott, M. D. Fayer, J. R. Salcedo, and A. E. Siegman, "Energy Transport in Molecular Solids: Application of the Picosecond Transient Grating Technique," in Picosecond Phenomena, edited by C. V. Shank, E. P. Ippen, and S. L. Shapiro, Springer-Verlag, Berlin, 1978, 240-243.

frequency equal to the optical difference frequency. The excited-state pattern induced in the sample will then follow or not follow these moving fringes, depending upon whether the excited state response time τ is short or long compared to the frequency f_d. For $f_d \leq 1/\tau$ the excited states will follow the moving fringes; there will be a (moving) grating pattern in the sample; and a third or probe laser beam will be diffracted. For $f_d \geq 1/\tau$ the excited states will not be able to follow the moving fringes; the grating pattern will be washed out, i.e. no grating will be produced; and the probe diffraction will disappear. Plotting diffracted probe intensity versus difference frequency f_d between the excitation beams and looking for the break frequency at which diffraction begins to fall as f_d^{-2} should yield the time constant τ. For simple cases the relation between lifetime and break frequency is

$$f_d(\mathrm{cm}^{-1})\ \tau(\mathrm{psec}) \approx 5.3$$

Thus, a time constant of 0.1 psec (100 femtoseconds) corresponds to 50 cm^{-1} of tuning, which is easily achieved with modern dye lasers. This technique should become most useful just where conventional picosecond or subpicosecond pulse techniques become impossibly difficult.

[5.5] J. R. Salcedo, A. E. Siegman, D. D. Dlott, and M. D. Fayer, "Dynamics of Energy Transport in Molecular Crystals: The Picosecond Transient Grating Method," Phys. Rev. Lett. 41, 131-134 (10 July 1978).

[5.6] J. R. Salcedo and A. E. Siegman, "Laser Induced Photoacoustic Grating Effects in Molecular Crystals," IEEE J. Quant. Electr. QE-15, 250-256 (April 1979).

[5.7] A. E. Siegman, "Grating Spectroscopy," Invited paper, Conference on Dynamical Processes of Excited States in Solids, Madison, Wisconsin, June 18-20, 1979.

II. PROGRESS TO DATE: EXPERIMENT

Because the diffraction efficiency in the tunable laser-induced grating experiment will be comparatively weak, and yet the samples involved generally will not be able to withstand very high peak intensities, the tunable laser and probe systems need to supply long, medium-intensity, high-rep-rate, stable, and readily tunable beams. A high-rep-rate Q-switched Nd:YAG laser pumping three independently tunable dye lasers was selected as the best available way of meeting these requirements. Assembly of this apparatus necessarily started from scratch, since no existing system of this type was available in our laboratory for this project.

During the first year the basic flash-pumped and Q-switched Nd:YAG laser with power supplied and timing equipment has been assembled and put into operation on the laboratory table that will be used for these experiments. Repetition rates to at least 200 Hz are available. Saturable absorber Q-switching of the laser has been used to date, but we are awaiting the (long overdue!) arrival from a commercial vendor of an electrooptic Q-switch.

While this laser as it stands will be suitable as planned, it would be considerably more useful for our purposes if its output could be stretched from the normal Q-switched pulse length of 20-50 nsec to yield the same total energy output but in ~ 1 μsec or longer. No easy techniques for doing this are known at present. We have considered that it may be

possible to accomplish this by using a fast high-voltage feedback circuit driving a programmed Pockels-cell Q-switch in the laser. Kilovolt feedback signals with nsec time constant are required. These may be obtainable using fast ceramic planar microwave triodes. Design and construction of such a circuit is presently being undertaken by an overseas visitor in our group, at no salary charges to the project. His efforts, if successful, will be directly usable on our apparatus.

Assembly of the tunable dye lasers for this project, to be pumped by the doubled output of the Nd:YAG laser, is well under way. There have been significant advances made in other laboratories in the technology of such lasers during the past year. One year ago the newest design for such lasers employed a grating used a grazing incidence ($\leq 1^{\circ}$ angle) to obtain narrow linewidth. This design, although it had rather poor energy efficiency, achieved good time narrowing even in 20 nsec pulses; and was our initial choice for this project. More recently, however, attention has shifted to a new arrangement developed at Rice University which uses a reflective cassegiainian beam expander and a grating in the Littrow configuration at its blaze angle.[8] This design yields apparently all the desirable features: short cavity length, narrow linewidth, efficient feedback, good energy conversion, ease of tuning, and low-cost optics; and we have therefore switched to it. The components we had already purchased for our initial design (including gratings) are also usable for the new design; and most of the machined parts are also now in hand. Assembly of the dye lasers will proceed directly.

[5.8] E. J. Beiting and K. A. Smith, "An On-Axis Reflective Beam Expander for Pulsed Dye Laser Cavities," Optics Comm. 28(3), 355-358 (March 1979); E. J. Beiting, "The Use of A Concave Grating in Pulsed Dye Laser Cavities," Optics Comm. 29(2), 209-212 (May 1979).

A DEC MINC-11 laboratory computer with laboratory modules has also been obtained in our group, at no charge to this project, and will be available for data acquisition.

It is important to be able to measure and monitor the excitation laser wavelength or frequency on a continuous basis during the experiments. The Snyder type of wavemeter using a Fizeau wedge[9] appears to be very well suited to our needs, especially for measuring the frequency difference f_d between two lasers with good accuracy. During the past quarter we have designed such a wavemeter for our system; and set up and tested a prototype using a He-Ne laser, quartz wedge, TV vidicon as fringe detector, and the MINC computer for data acquisition and transformation. This technique will clearly be suitable for our needs, although we will still have to solve some additional problems after the dye lasers become operational, including deciding how to put beams from both excitation lasers through one wavemeter, and writing software to collect data from the wavemeter with a pulsed laser on the fly.

5.9 J. J. Snyder, "Compact Static Wavelength Meter for Both Pulsed and cw Lasers," Sov. J. Quant. Electr. 8(8), 959-960 (August 1978).

III. PROGRESS TO DATE: THEORY

We are planning to apply the tunable laser-induced grating method eventually to a wide variety of physical systems, including:

- -- rotational and fluorescent lifetimes in organic dye solutions and in large molecular complexes
- -- excited-state and carrier lifetimes in semiconductors
- -- exciton diffusion processes in one-dimensional organic crystals
- -- excitation, relaxation, and gain-recovery rates in solid-state laser materials
- -- excitation process in color centers that are potentially useful as "eye-safe" IR laser systems
- -- vibrational relaxation processes in liquids
- -- lifetime measurements in dye used for laser Q-switches mode-lockers, and optical Kerr cells

As the second year of this program opens we are actively engaged in reviewing the literature and assembling detailed information on subpicosecond phenomena[10] in all of these systems. A large amount of material has been collected but not written up in detail. This information will be summarized in the next report.

[5.10] Erich P. Ippen and Charles V. Shank, "Sub-Picosecond Spectroscopy," Physics Today, 41-47 (May 1978).

We expect that initial measurements will be aimed at measuring the vibrational relaxation time in a typical organic dye molecule, probably Rhodamine B, a common laser dye which operates somewhat to the red of Rhodamine 6G, and should therefore be pumpable by our tunable dye lasers. The vibrational relaxation time in this system is known only to be < 200 femtoseconds.[11,12]

We also have a new graduate student arriving this autumn who has had previous experience on measuring fast processes in semiconductors, and who will immediately begin work on applying this technique to semiconductors such as GaAs, Ge and very likely sapphire-on-silicon (SOS) thin films.

IV. OBJECTIVES FOR THE COMING PERIOD

The objectives for the second year are to finish assembling and put into operation the experimental apparatus; test its operation with an appropriate trial system; and begin obtaining significant scientific results with the apparatus.

[5.11] C. V. Shank, E. P. Ippen, and Omar Teschke, "Subpicosecond Relaxation of Large Organic Molecules in Solution," private communication (to be published).

[5.12] W. T. Barnes and F. E. Lytle, "Fluorescence Decay Measurement via Modulated Gain Spectroscopy," Appl. Phys. Lett. 34(8), 509-511 (15 April 1979).

UNIT 6

A VUV AND SOFT X-RAY LIGHT SOURCE

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A. Measurement of the He $1s2s\,^1S_0$ Isotopic Shift

High resolution vacuum ultraviolet (VUV) spectroscopy has traditionally been limited by the lack of bright sources and by the low efficiency and resolution of spectrometers. Many of these difficulties can be reduced by making use of the high brightness, tunability, and narrow linewidth of the recently demonstrated spontaneous anti-Stokes VUV source.[6.1,6.2] We have illustrated one such application by directly measuring the isotopic shift of the He $1s^2\,^1S_0 - 1s2s\,^1S_0$ transition at 166,277 cm^{-1} (20.6 eV) to a resolution of ± 0.5 cm^{-1} (60 μeV). The technique does not require any VUV optics or detectors.

In this experiment a cw glow discharge in a mixture of He and Ne creates population in the He $2s\,^1S$ metastable level. A tunable laser pump field of frequency ω_p interacts with this population to produce tunable VUV spontaneous anti-Stokes radiation having a photon energy equal to $\hbar\omega_p$ plus the energy of the metastable level. The pump frequency is tuned until

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[6.1] S. E. Harris, "Spontaneous Anti-Stokes Scattering as a High Resolution and Picosecond Time Scale VUV Light Source," Appl. Phys. Lett. 31, 498 (1977).

[6.2] L. J. Zych, J. Lukasik, J. F. Young, and S. E. Harris, "Laser Induced Two-Photon Blackbody Radiation in the Vacuum Ultraviolet," Phys. Rev. Lett. 40, 1493 (1978).

the frequency of the generated anti-Stokes radiation corresponds to the Ne $2p^6\ {}^1S_0 - 2p^5 7s'[1/2]^0_1$ transition at 583.7 Å, and the Ne, acting as a narrow band detector, absorbs the radiation and fluoresces on the $2p^5 7s'[1/2]^0_1 - 2p^5 3p'[3/2]_2$ transition at 4886 Å. The energy of the He $2s\,{}^1S$ level is therefore determined by the known energy of the Ne $2p^5 7s'$ state and the value $\hbar\omega_p$ which corresponds to its excitation. Separate experiments using ^{3}He and ^{4}He were performed to determine the isotopic shift. Using the published[6.3] energy for the Ne $7s'$ state of 171,324.0 cm^{-1} and our own calibration of ω_p we calculate the ^{4}He $2s\,{}^1S$ energy to be 166,277.3 ± 0.5 cm^{-1}, in agreement with its published value.[6.4] We find the energy of the ^{3}He $2s\,{}^1S$ state to be 7.8 ± 0.5 cm^{-1} lower, consistent with an experimentally inferred value of 8.1 cm^{-1}.[6.5]

This work represents the first direct measurement of the He $2s\,{}^1S$ isotopic shift, and illustrates the potential of this technique for performing high resolution VUV spectroscopy without the limitations of traditional VUV apparatus. In this experiment the known Ne $7s'$ target state was used to characterize the He storage states, but in other applications known source properties could be used to study VUV absorber states, such as the inner shell transitions of K or Rb. Extensions to shorter wavelengths using an ionic storage state, such as Li II $1s2s\,{}^1S_0$ at 199 Å, should be possible. Finally, we note that the use of a mode-locked pump

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[6.3] V. Kaufman and L. Minnhagen, "Accurate Ground-Term Combinations in Ne I," J. Opt. Soc. Am. 62, 92 (1972).

[6.4] W. C. Martin, "Energy Levels and Spectrum of Natural Helium," NBS Journal of Research A 64, 19 (1960).

[6.5] L. C. Bradley and H. Kuhn, "Isotope Shifts in the Spectrum of Helium," Proc. Royal Soc. (London) A 209, 325 (1951).

laser would facilitate time resolved studies of VUV fluorescence and autoionization.

B. VUV Anti-Stokes Light Source Used in High Resolution Absorption Spectroscopy

We have been working on various aspects of a helium anti-Stokes VUV light source to be used as a spectroscopic device. We have been concerned mainly with enhancing the signal-to-noise ratio. This has led to an analysis of a longitudinal geometry shown in Fig. 6.1.

A tunable, pulsed laser is injected into a He glow discharge. The generated, tunable, narrow band, VUV light is collected down the bore. The VUV light passes through a long cell of neutral, unexcited He gas which will filter out the main noise sources: the He resonance lines. The VUV light then passes through an absorption cell, then the spectrometer, and is detected. We note that, based on how well the He filter blocks the resonance lines, we may be able to remove the spectrometer from the system. This would make the device an extremely attractive and simple one. We plan to study various inner shell excitations of alkali metals with this device.

The source, for our first application, and its energy level diagram are shown in Fig. 6.2. The tunable pump laser illuminates a length L of He discharge. The anti-Stokes generation process is merely a scattering process. A certain fraction of the incident photon flux is scattered (now at the tunable sum frequency $\omega_{1s2s} + \omega_p$) into 4π steradians. This fraction is a function of the cross section, the density of He 1s2s metastables, and the length, L, of the interaction. Thus, the number

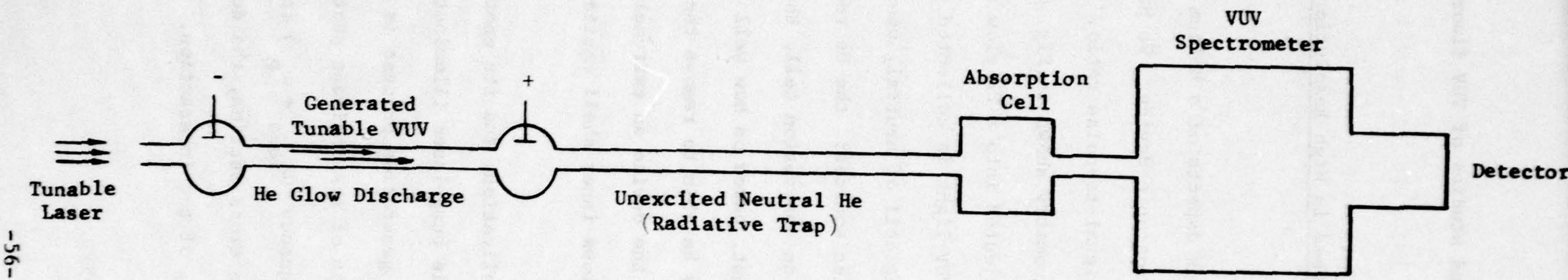

Fig. 6.1--Anti-Stokes VUV light source used as a spectroscopic device.

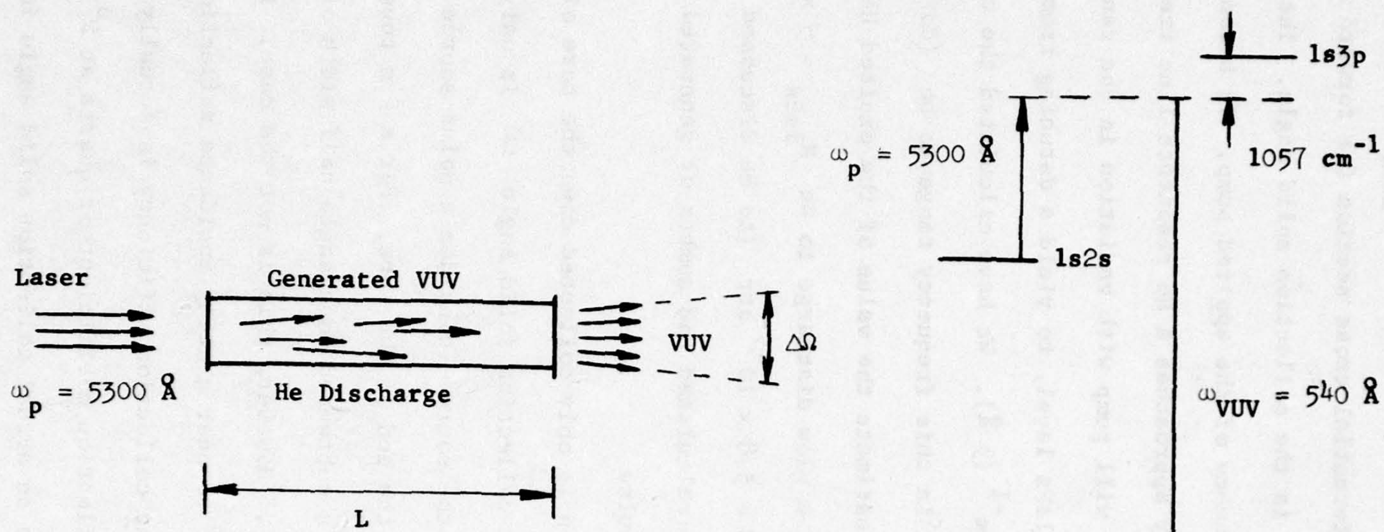

Fig. 6.2--He anti-Stokes VUV source.

of generated VUV photons is $n_{VUV} = n_{pump}\ (d\sigma/d\Omega)\ N_{1s2s} L(\Delta\Omega)$, where n_{pump} is the number of incident pump photons, N_{1s2s} is the He 1s2s density, $d\sigma/d\Omega$ is the differential cross section for forward anti-Stokes scattering, and $\Delta\Omega$ is the collection solid angle. The cross section depends on the frequency of the applied pump. It becomes very large when the VUV frequency approaches a He resonance line frequency. In our first application we will pump with radiation in the range 5300 Å ± 30 Å, scatter off the He 1s2s level, to yield a detuning from the He 3p resonance line of 1057 cm^{-1} (3 Å). We have calculated the cross section for forward scattering in this frequency range to be $(d\sigma/d\Omega) = 1.42 \times 10^{-23}\ cm^2/str$. We estimate the value of the excited He 1s2s metastable density found in a glow discharge to be $N_{1s2s} = 5 \times 10^{11}\ cm^{-3}$. With a 20 cm discharge, $\Delta\Omega = 3.8 \times 10^{-3}$ str (to be discussed below), and a 15 mJ pump pulse, we have calculated the number of generated VUV photons to be $n_{VUV} = 10^5$ photons/pulse .

Since the VUV radiation is only collected down the bore of the discharge, one would think the collection solid angle $\Delta\Omega$ is only the solid angle that is subtended to the source (consider a point source for the moment) by the aperture at the end of the tube. For a 2 m tube of diameter 4 mm this would imply a subtended cone angle half width of 10^{-3} rad $\cong 0.06^o$ or $\Delta\Omega = 3 \times 10^{-6}$. However, this is not the case. Preliminary calculations show that, due to near grazing incidence reflections off the inside wall of the tube, the collection efficiency is actually much higher. The fact that the power reflection coefficient of quartz at 2^o to grazing is still about 90% leads to an actual collection solid angle for the case above of $\Delta\Omega = 2 \times 10^{-3}$. In fact, we have calculated that as the tube

becomes longer $\Delta\Omega$ decreases so slowly that the product $\Delta\Omega L$ increases. This would imply, since the number of generated photons is proportional to $\Delta\Omega \times L$, that by making longer discharge tubes we could significantly increase our VUV output. This result could also be enhanced by having many such tubes, passing the laser through all of them, and collecting all of the VUV light.

The final point to mention about grazing incident collection is that the long tube used as a radiative trap does not represent a large loss of signal. We will try to take advantage of this and thereby improve our signal-to-noise. We will be investigating, experimentally, the transmission of VUV through long small diameter tubes to verify our calculations. The experimental apparatus will be the same as for the work on the neutral He radiative trap, which we will now discuss.

The He resonance lines at 537 Å and 584 Å are the primary sources of noise in the measurements we will be doing. We are going to pass the VUV light generated in the discharge (this includes resonance radiation and anti-Stokes radiation) through a long, high pressure (10-50 torr) tube of unexcited neutral He. The anti-Stokes radiation should pass through unattenuated, but the resonance lines will be attenuated due to a physical process known as radiative trapping. This refers to the fact that resonance line photons cannot travel more than a few microns (at a few torr of pressure) without being absorbed by a He atom.

We have been calculating the magnitude of this attenuation. The results are unclear because of contributions very far from line center. We are in the process of measuring this attenuation as a function of unexcited He cell length and pressure using the apparatus shown in Fig. 6.3.

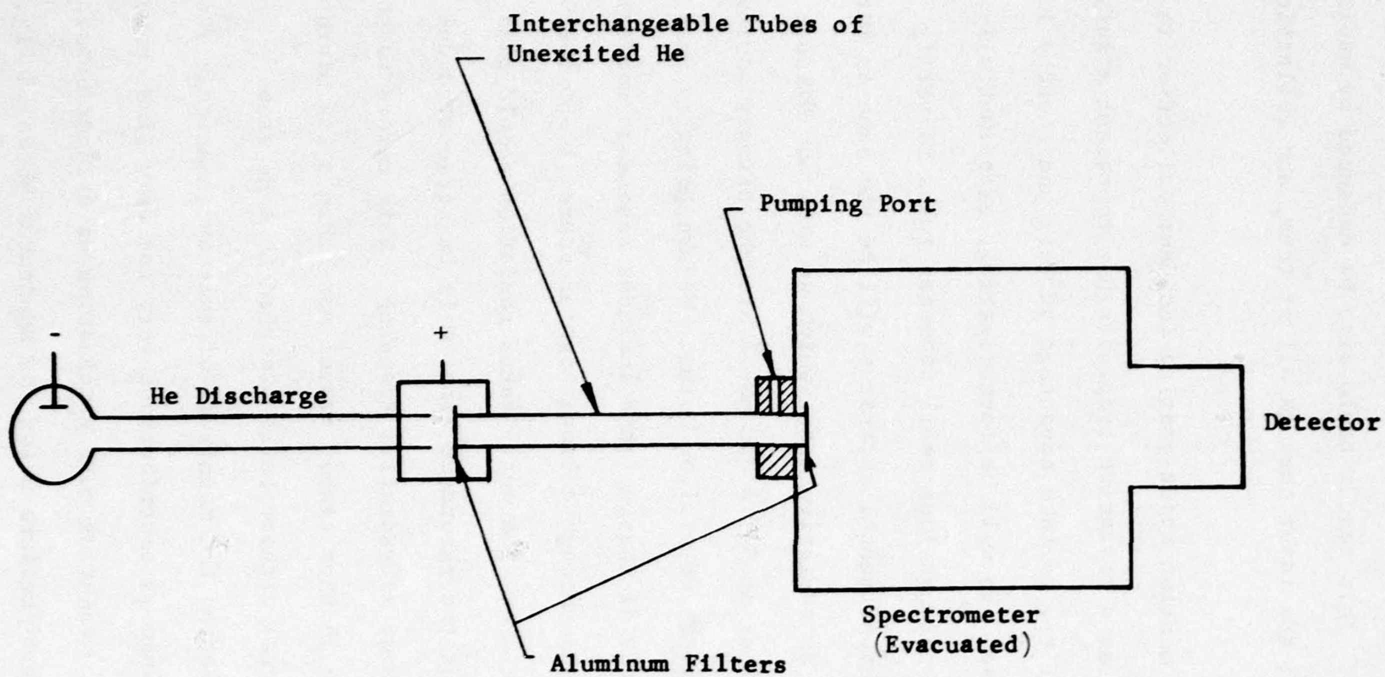

Fig. 6.3--Apparatus used for measuring transmission through an unexcited He radiative trap.

This apparatus will allow interchangeability of tube lengths which will be evacuated and then filled with various pressures of He. The pressure differences in the apparatus will be maintained by thin aluminum filters which transmit the VUV. The measured transmission as a function of pressure can then be compared to the evacuated transmission, and the attenuation due to the presence of unexcited He can be determined. Grazing incidence collection efficiencies are easily measured with this apparatus by comparing transmissions of various lengths of evacuated tubing.

Our work on a spectroscopic device using a He anti-Stokes light source is continuing. We have been analyzing, and will soon experimentally determine, the plausibility of eliminating a spectrometer from the system, and replacing it with a long tube of unexcited He.

JSEP Publications

N00014-75-C-0632

1. S. E. Harris, J. Lukasik, J. F. Young, and L. J. Zych, "Anti-Stokes Emission as a VUV and Soft X-Ray Source," in Picosecond Phenomena, C. V. Shank, E. P. Ippen, and S. L. Shapiro, eds. (New York: Springer-Verlag, 1978).

2. R. W. Falcone, J. R. Willison, J. F. Young, and S. E. Harris, "Measurement of the He $1s2s^1S_0$ Isotopic Shift Using a Tunable VUV Anti-Stokes Light Source," Optics Lett. 3, 162 (November 1978).

3. S. E. Harris and J. F. Young, "Techniques for Rapid Laser Induced Energy Transfer Using Metastable States," in Proceedings for the International Conference on Lasers '78.

REPORTS AND PUBLICATIONS OF THE

EDWARD L. GINZTON LABORATORY FACULTY AND STAFF

G.L. No.	Report	Contract
2800	Peter Borden, "The Storage Correlator: Theory and Signal Processing Applications," Technical Report and Special Research Report (April 1978).	N00014-76-C-0129
2801	Staff, "Research Studies on Radiative Collision Lasers," Interim Technical Report covering the period 10 March 1977 – 9 March 1978 (April 1978).	F19628-77-C-0072
2802	Staff, "Innovative Measurement Technology for the Semiconductor Device Industry – 'The Acoustic Microscope – A New Instrument for Viewing Integrated Circuits'," Quarterly Report covering the period 1 January – 31 March 1978 (March 1978).	NBS 5-35899
2803	Staff, "Acoustic Techniques for Measuring Stress Regions in Materials," 29th Monthly Report for March 1978 (April 1978).	EPRI RP609-1
2804	R.A. Baumgartner and R.L. Byer, "Remote SO_2 Measurements at 4 μm with a Continuously Tunable Source," Preprint (April 1978). Also: Published in Optics Letters Vol. 2, 163-165 (June 1978).	SRI 14307
2805	Staff, "Laser Physics and Laser Techniques," Annual Technical Report for the year 1 January – 31 December 1977 (April 1978).	F49620-77-C-0092
2806	G.S. Kino, J.B. Hunter, G.C. Johnson, A.R. Selfridge, D.M. Barnett, G. Herrmann, and C.R. Steele, "Acoustoelastic Imaging of Stress Fields," Preprint (April 1978). Presented at the First International Symposium on Ultrasonic Materials Characterization, Gaithersburg, Maryland (June 1978).	EPRI RP609-1
2807	Staff, "Acoustically Scanned Optical Imaging Devices," Management Report covering the period 1 January – 31 March 1978 (April 1978).	N00014-76-C-0129

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G.L. No.	Report	Contract
2808	B. A. Auld, "General Electromechanical Reciprocity Relations Applied to the Calculation of Elastic Wave Scattering Coefficients," Preprint (April 1978). To appear in Wave Motion.	RISC 77-70946
2809	Staff, "Research Studies on Techniques for High Power Lasers Using Metastable Energy Storage," Quarterly Report for the period 1 February — 30 April 1978 (May 1978).	ERDA EY-76-S-03-0326, P.A. 60
2810	S. E. Harris and J. F. Young, "Rapid Laser Induced Energy Transfer in Atomic Systems," Reprinted from Radiation Energy Conversion in Space, vol. 61, of Progress in Astronautics and Aeronautics (1978).	F19628-77-C-0072 and NASA NGL-05-020-103
2811	Staff, "Studies of Techniques for Generation of Vacuum Ultraviolet and Soft X-Ray Laser Radiation," Final Report covering the period 1 October 1976 — 30 April 1978 (May 1978).	N00014-75-C-0576
2812	Staff, "Tunable Lasers and Coherent Light Techniques for High Resolution Ultraviolet Spectroscopy," Final Technical Report covering the period 1 April 1975 — 31 March 1978 (May 1978).	N00014-75-C-0841
2813	P.D. Corl, G.S. Kino, C.S. DeSilets, and P.M. Grant, "A Digital Synthetic Focus Acoustic Imaging System," Preprint (May 1978). Presented at the Acoustical Imaging 8th Internation Conference at Key Biscayne, Florida, May 29 - June 2, 1978.	RISC RI74-20773
2814	V. Domarkas, B.T. Khuri-Yakub, and G.S. Kino, "Length and Depth Resonances of Surface Cracks and Their Use for Crack Size Estimation," Preprint (May 1978). Also: Published in Applied Physics Letters, Vol. 33, No. 7, 557-559 (1 October 1978).	N00014-78-C-0283

G.L. No.	Report	Contract
2815	G.S. Kino, T.M. Waugh, P.D. Corl, C.S. DeSilets, and P.M. Grant, "Acoustic Imaging Techniques for Nondestructive Testing," Preprint (May 1978). Presented at the First International Symposium on Ultrasonic Materials Characterization at Gaithersburg, Maryland in June 1978.	RISC RI74-20773
2816	Staff, "Research on New Approaches to Optical Systems for Inertial Rotation Sensing," Interim Report for the period 1 June 1976 — 30 September 1977.	AFOSR-76-3070
2817	Staff, "Acoustic Techniques for Measuring Stress Regions in Materials," Thirtieth Monthly Report for April 1978 (May 1978).	EPRI RP609-1
2818	J.C. White and G.A. Zdasiuk, "Branching Ratios for TℓBr Photodissociation with 2660 Å Radiation," Preprint (June 1978). Also: Published in the Journal of Chemical Physics, Vol. 69, No. 5, 2256-2257 (1 September 1978).	F19628-77-C-0072 and ERDA EY-76-S-03-0326, PA 60
2819	S.E. Harris, J. Lukasik, J.F. Young, and L.J. Zych, "Anti-Stokes Emission as a VUV and Soft X-Ray Source," Preprint (June 1978). Also: Published in Picosecond Phenomena, eds. C.V. Shank, E.P. Ippen, and S.L. Shapiro, New York: Springer-Verlag, 1978.	NASA NGL-05-020-103, N00014-75-C-1175,and N00014-75-C-0632
2820	Staff, "Innovative Measurement Technology for the Semiconductor Device Industry — 'The Acoustic Microscope — A New Instrument for Viewing Integrated Circuits,'' Quarterly Report for the period April — June 1978 (June 1978).	NBS 5-35899
2821	R.E. Teets, "Polarization Labeling Spectroscopy of Molecules," Internal Memorandum and Special Research Report, July 1978.	NSF PHY77-09687

G.L. No.	Report	Contract
2822	M.T. Resch, B.T. Khuri-Yakub, G.S. Kino, and J.S. Shyne, "Stress Intensity Factor Measurement of Surface Cracks," Preprint (June 1978). Presented at the First International Symposium on Ultrasonic Materials Characterization, Gaithersburg, Maryland, June 1978.	NSF DMK-76-00726
2823	G.S. Kino, J.B. Hunter, G.C. Johnson, A.R. Selfridge, D.M. Barnett, G. Herrmann, and C.R. Steele, "Measurement of Stress Fields in Metals," Preprint (June 1978).	EPRI RP609-1 and NSF DMK-76-00726
2824	G.S. Kino, "Acoustic Imaging for Nondestructive Evaluation," Preprint (June 1978).	RISC RI74-20773 and EPRI RP609-1
2825	Y. Murakami, B.T. Khuri-Yakub, G.S. Kino, J.M. Richardson, and A.G. Evans, "The Application of Adaptive Filtering to Defect Characterization," Preprint (June 1978). Presented at the First International Symposium on Ultrasonic Materials Characterization, Gaithersburg, Maryland, June 1978.	RISC RI74-20773
2826	W. A. Harrison, "Fifty Years of Metals Theory," Preprint (June 1978). To appear in Felix Bloch and Twentieth Century Physics, published by Rice Studies, Rice University.	NSF DMR 77-21384
2827	Staff, "Acoustic Techniques for Measuring Stress Regions in Materials," Thirty-First Monthly Report for May 1978 (June 1978).	EPRI RP609-1
2828	Y. Murakami, B.T. Khuri-Yakub, G.S. Kino, J.M. Richardson, and A.G. Evans, "An Application of Wiener Filtering to Nondestructive Evaluation," Preprint (June 1978). Also: Published in Applied Physics Letters, Vol. 33, No. 8, 685-687 (15 October 1978).	RISC RI74-20773
2829	Staff, "Research Studies on Radiative Collision Lasers," Quarterly Report for the period 10 March — 9 June 1978 (June 1978).	F19628-77-C-0072

G.L. No.	Report	Contract
2830	A.I. Ferguson, J.N. Eckstein, and T.W. Hänsch, "A Subpicosecond Dye Laser Directly Pumped by a Mode-Locker Argon Laser," Preprint (June 1978). Also: Published in Journal of Applied Physics, Vol. 49, No. 11, 5389 (November 1978).	N00014-75-C-0841
2831	J.N. Eckstein, "High Resolution Spectroscopy Using Multiple Coherent Interactions," Internal Memorandum and Special Research Report (August 1978).	N00014-75-C-0841
2832	F.V. Kowalski, "New Methods in Laser Spectroscopy," Internal Memorandum and Special Research Report (August 1978).	NSF PHY77-09687
2833	C.S. DeSilets, "Transducer Arrays Suitable for Acoustic Imaging," Internal Memorandum and Special Research Report (June 1978).	N00014-75-C-0632 and RISC RI74-20773
2834	B.A. Auld, G. Elston, and D.K. Winslow, "A Novel Microwave Ferromagnetic Resonance Probe for Eddy Current Detection of Surface Flaws in Metals," Preprint (June 1978). To appear in the Proceedings of the 8th European Microwave Conference, Paris, September 1978.	NSF DMR76-00726
2835	P.M. Grant and G.S. Kino, "Adaptive Filter Based on SAW Monolithic Storage Correlator," Preprint (July 1978). Also: Published in Electronics Letters, Vol. 14, No. 17, pp. 562-564 (17 August 1978).	N00014-76-C-0129
2836	R.A. Baumgartner and R.L. Byer, "Continuously Tunable IR Lidar with Applications to Remote Measurements of SO_2 and CH_4," Preprint (July 1978). To appear in Applied Optics, Vol. 17 (15 November 1978).	SRI-14307

G.L. No.	Report	Contract
2837	R.W. Falcone, J.R. Willison, J.F. Young, and S.E. Harris, "Measurement of the He $1s2s\,^1S_0$ Isotopic Shift Using a Tunable VUV Anti-Stokes Light Source," Preprint (July 1978). To appear in Optics Letters, Vol. 3, November 1978.	N00014-78-C-0403
2838	G.S. Kino, P.M. Grant, P.D. Corl, and C.S. DeSilets, "Digital Synthetic Aperture Acoustic Imaging for NDE," Preprint (July 1978). Presented at the ARPA/AFML Review of Progress in Quantitative NDE at LaJolla, California (July 1978).	RISC RI74-20773
2839	B.A. Auld, "Theory of Ferromagnetic Resonance Probes for Surface Cracks in Metals," Preprint (July 1978).	NSF DMR76-00726
2840	Staff, "Generation of Coherent VUV and Soft X-Rays," Final Report for the period 1 July 1974 — 30 June 1978 (July 1978).	N00014-75-C-1175
2841	Staff, "Optical Picosecond Viewing of Biological Material," Final Scientific Report for the period 1 September 1976 — 28 February 1978 (June 1978).	NSF ENG76-11230
2842	Staff, "Tunable Optical Sources," Semi-annual Report No. 2 for the period 1 January — 30 June 1978 (July 1978).	DAAG29-77-G-0221
2843	H.K. Wickramasinghe, "Contrast and Imaging Performance in the Scanning Acoustic Microscope," Preprint (July 1978). To appear in Journal of Applied Physics (November 1978).	NSF ENG75-02030 and AFOSR-77-3455
2844	G.S. Kino, "Acoustoelasticity," Preprint (July 1978). An Invited Paper for the ASME Conference, San Francisco, December 1978.	EPRI RP609-1 and NSF DMK76-00726
2845	F.V. Kowalski, R.E. Teets, W. Demtröder, and A.L. Schawlow, "An Improved Wavemeter for CW Lasers," Preprint (July 1978). To appear in the Journal of the Optical society of America.	NSF PHY77-09687

G.L. No.	Report	Contract
2846	R.E. Howard, D.A. Rudman, and M.R. Beasley, "Josephson Properties of Nb_3Sn/Pb Tunnel Junctions," Preprint (July 1978). Also: Published in Applied Physics Letters, Vol. 33, #7, 671-673 (1 October 1978).	N00014-77-C-0439
2847	Staff, "Acoustic Techniques for Measuring Stress Regions in Materials," Thirty-Second Monthly Report for 1 June - 31 July 1978 (August 1978).	EPRI RP609-1
2848	Staff, "Acoustic Wave Phenomenon for Signal Processing," Final Report period ending 31 March 1978 (August 1978).	NSF ENG75-18681
2849	Staff, "Research Studies on Techniques for High Power Lasers Using Metastable Energy Storage," Final Report for the period 1 August 1977 — 31 July 1978 (August 1978).	ERDA EY-76-S-03-0326, PA 60
2850	H.K. Wickramasinghe, R.C. Bray, V. Jipson, C.F. Quate, and J.R. Salcedo, "Photo-acoustics on a Microscopic Scale," Pre-print (August 1978). To appear in the Applied Physics Letters November 15, 1978 issue.	AFOSR-77-3455
2851	M.T. Resch, B.T. Khuri-Yakub, G.S. Kino, and J.C. Shyne, "The Acoustic Measurement of Stress Intensity Factors," Preprint (August 1978). Accepted for publication in Applied Physics Letters.	NSF DMK76-00726
2852	Staff, "Ultrashort Pulses at CO_2 Wave-lengths," Final Report covering the period 1 April 1977 — 31 March 1978 (April 1978).	ERDA EY-76-S-03-0326 PA 56
2853	J.C. White, G.A. Zdasiuk, J.F. Young, and S.E. Harris, "Observation of Radiative Collisional Fluorescence," Preprint (August 1978).	F19628-77-C-0072
2854	Staff, "Investigation of Laser Dynamics, Modulation and Control by Means of Intra-Cavity Time Varying Perturbation," Semiannual Report for the period 1 March — 31 August 1978 (September 1978).	NASA NGL-05-020-103

G.L. No.	Report	Contract
2855	S.J. Poon and J. Durand, "Magnetic Clusters Description of Spin Glasses in Amorphous La-Gd-Au Alloys," Preprint (August 1978). To appear in Physical Review B.	F49620-78-C-0009
2856	A. L. Schawlow, "Laser Spectroscopy of Atoms and Molecules," Preprint (August 1978). To appear in Science.	NSF PHY77-09687
2857	R.L. Byer and W.R. Trutna, "16-μm Generation by CO_2-Pumped Rotational Raman Scattering in H_2," Reprint from Optics Letters, Vol. 3, 144-146 (October 1978).	Exxon Grant-in-Aid and F49620-77-C-0092
2858	Staff, "Electronic Structure of Transition Metal Compounds," Final Report for the period 1 May 1973 — 30 September 1978 (September 1978).	DAAG29-73-C-0024 and DAAG29-77-C-0022
2859	B.T. Khuri-Yakub, G.S. Kino, J.C. Shyne, M.T. Resch, and V. Domarkas, "Surface Crack Characterization: Geometry and Stress Intensity Factor Measurements," Preprint (September 1978). To appear in Proc. ARPA/AFML Review of Progress in Quantitative NDE.	NSF DMK-76-00726 and N00014-78-C-0283
2860	Staff, "Acoustic Techniques for Measuring Stress Regions in Materials," Thirty-third Monthly Report for August 1978 (September 1978).	EPRI RP609-1
2861	S.J. Poon, "The Range of Indirect Exchange Interaction in an Amorphous Magnet," Preprint (September 1978). To be published in Physics Letters A.	F49620-78-C-0009
2862	P.D. Corl, P.M. Grant, and G.S. Kino, "A Digital Synthetic Focus Acoustic Imaging System for NDE," Preprint (September 1978). To appear in the Proceedings of the 1978 Ultrasonics Symposium.	RISC RI74-20773
2863	E.W. Weber and J.E.M. Goldsmith, "Double-Quantum Saturation Spectroscopy in Hydrogen: Measurement of the $3P_{3/2}$-$3D_{3/2}$ Lamb Shift," Preprint (September 1978). Also: Published in Physical Review Letters, Vol. 41, #14, 940-944 (2 October 1978).	NSF PHY77-09687

G.L. No.	Report	Contract
2864	Staff, "Research Studies on Radiative Collision Lasers," Quarterly Report for the period 10 June — 9 September 1978 (September 1978).	F19628-77-C-0072
2865	Staff, "Acoustic Microscopy at Cryogenic Temperatures," Annual Summary Report for the period 1 July 1977 — 30 June 1978 (September 1978).	N00014-77-C-0412
2866	C.S. DeSilets, A.R. Selfridge, and G.S. Kino, "Highly Efficient Transducer Arrays Useful in Nondestructive Testing Applications," Preprint (September 1978). To appear in the 1978 Ultrasonics Symposium Proceedings.	RISC RI74-20773 and N00014-75-C-0632
2867	J.E. Bowers, B.T. Khuri-Yakub, G.S. Kino, and K-H Yu, "Design and Applications of High Efficiency Wideband SAW Edge Bonded Transducers," Preprint (September 1978). To appear in the 1978 Ultrasonics Symposium Proceedings.	N00014-76-C-0129 and NSF ENG77-28528
2868	S. Early and T.H. Geballe, "Silicon-on-Sapphire Thermometer for Low-Temperature Small Sample Calorimetry," Preprint (September 1978).	F49620-78-C-0009
2869	G. Herrmann and G.S. Kino, "Ultrasonic Measurements of Inhomogeneous Stress Fields," Preprint (September 1978). To appear in the Proceedings of the ARPA/AFML Conference on NDE, La Jolla, California.	EPRI RP609-1 and NSF DMK76-00726
2870	B.T. Khuri-Yakub, G.S. Kino, and Y. Murakami, "Ultrasonic Wave Scattering for Defect Characterization Applied to Ceramic Materials," Preprint (October 1978). Presented at the 38th International Symposium of ASNT at Denver Colorado.	RISC RI74-20773
2871	A.J. Duerinckx, H.A. Vanherzeele, J.-L. Van Eck, and A.E. Siegman, "Pulse Compression Inside an Actively AM Mode-Locked Nd:YAG Laser Using a Liquid Kerr Cell," Reprint from IEEE Journal of Quantum Electronics, Vol. QE-14, No. 12, 983-992 (December 1978).	NASA NGL 05-020-103

G.L. No.	Report	Contract
2872	H.C. Tuan, P.M. Grant, and G.S. Kino, "Theory and Application of Zinc-Oxide-on-Silicon Monolithic Storage Correlators," Preprint (October 1978). Also: Published in the Proceedings of the 1978 Ultrasonics Symposium, pp. 38-43.	N00014-76-C-0129
2873	A.G. Evans, B.R. Tittmann, L. Ahlberg, B.T. Khuri-Yakub, and G.S. Kino, "Ultrasonic Attenuation in Ceramics," Reprint from Journal of Applied Physics, Vol. 49, No. 5, 2669-2679 (May 1978).	RISC RI74-20773 and RI76-63282
2874	B.T. Khuri-Yakub and G.S. Kino, "High Frequency Ultrasonics," Preprint (October 1978). Presented at the Conference on Composites and Advanced Materials, Cocoa Beach, Florida.	RISC RI74-20773, RISC RI76-63282 and NSF ENG75-18681
2875	R.W. Falcone, "Inversion of Atoms and Molecules to the Ground State by Optical Pumping," Preprint (October 1978). Also: Published in Applied Physics Letters, Vol. 34, No. 2, 150-152 (15 January 1979).	N00014-78-C-0403 and F19628-77-C-0072
2876	R.E. Howard, "A Refractory Lift-Off Process with Applications to High-T_c Superconducting Circuits," Reprint from Applied Physics Letters, Vol. 33, No. 12, 1034-1035 (15 December 1978).	N00014-75-C-0632
2877	B.E. Jacobson, R.H. Hammond, T.H. Geballe, and J.R. Salem, "Transmission Electron Microscopy Studies of Electron Beam Co-evaporated Nb_3Sn-Cu Superconducting Composites," Preprint (April 1978). Also: Published in Thin Solid Films, Vol. 54, (1978), pp. 243-258.	F49620-78-C-0009

G.L. No.	Report	Contract
2878	Staff, "Acoustic Techniques for Measuring Stress Regions in Materials," 34th Monthly Report for 1-30 September 1978 (October 1978).	EPRI RP609-1
2879	D.F. Moore, R.B. Zubeck, J.M. Rowell, and M.R. Beasley, "Energy Gaps of the A15 Superconductors Nb_3Sn, V_3Si and Nb_3Ge Measured by Tunneling," Preprint (October 1978).	N00014-77-C-0439
2880	T.P. Orlando, E.J. McNiff, Jr., S. Foner, and M.R. Beasley, "Critical Fields, Pauli Paramagnetic Limiting, and Material Parameters of Nb_3Sn and V_3Si," Preprint (October 1978). Also: Published in Physical Review B, Vol. 19, No. 9, 4545-4561 (1 May 1979).	DOE EY-76-S-03-326, PA 43
2881	B.E. Jacobson, R.H. Hammond, T.H. Geballe, and J.R. Salem, "Microstructures of Electron-Beam Deposited Nb_3Sn and Nb_3Sn-Al_2O_3 Composites Related to their Superconducting Properties," Preprint (October 1978). Also: Published in Journal of the Less-Common Metals, Vol. 62, 59-87 (1978).	F49620-78-C-0009
2882	C.F. Quate, "Ultrasonic Imaging," Preprint (November 1978). Presented at The Rank Prize Funds, International Symposium on "Electronic Imaging," Royal Society, London, England, September 1978.	NSF APR75-07317 and AFOSR-77-3455
2883	Staff, "Acoustically Scanned Optical Imaging Devices," Management Report for the period 1 July - 30 September 1978 (November 1978).	N00014-76-C-0129
2884	A. Atalar, V. Jipson, R. Koch, and C.F. Quate, "Acoustic Microscopy with Microwave Frequencies," Preprint (November 1978). To be published in Annual Review of Materials Science, Vol. 9, August 1979.	F49620-78-C-0098

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2885	Staff, "Perturbation and Variational Studies of Acoustic Waveguide Problems," Annual Report for the period July 1977 through July 1978 (November 1978).	NSF ENG74-00334
2886	J.E.M. Goldsmith, E.W. Weber, and T.W. Hänsch, "A New Measurement of the Rydberg Constant Using Polarization Spectroscopy of H_α," Preprint (November 1978). Also: Published in Physical Review Letters, Vol. 41, No. 22, 1525-1528 (27 November 1978).	NSF PHY77-09687
2887	M.D. Duncan and R.L. Byer, "Very High Resolution CARS Spectroscopy in a Molecular Beam," Reprint from IEEE Journal of Quantum Electronics, Vol. QE-15, No. 2, 63-65 (February 1979).	NSF CHE76-21987
2888	Staff, "Acoustic Techniques for Measuring Stress Regions in Materials," 35th Monthly Report for 1 - 31 October 1978 (November 1978).	EPRI RP609-1
2889	S.E. Harris and J.F. Young, "Techniques for Rapid Laser Induced Energy Transfer Using Metastable States," Reprint from the Proceedings of the International Conference on Lasers, '78, pp. 679-688 (November 1978).	N00014-78-C-0403, N00014-75-C-0632, and F19628-77-C-0072
2890	Staff, "Acoustic Microscopic Study of Materials," Final Report covering the period 30 September 1977 - 30 September 1978 (November 1978).	AFOSR 77-3455
2891	Staff, "Nondestructive Failure Prediction in Ceramics Using Ultrasonics," End-of-the-Year Letter 1978 (December 1978).	N00014-78-C-0283
2892	Staff, "Quantitative Modeling of Flaw Responses in Eddy Current Testing," First Monthly Report for the period 15 October - 15 November 1978 (November 1978).	EPRI RP1395-3

G.L. No.	Report	Contract
2893	A. Rønnekleiv, H.J. Shaw, and J. Souquet, "Focusing Theory for Grating Acoustic Scanners," Technical Report (Decmeber 1978).	NSF ENG72-04217
2894	A. Atalar, "Acoustic Reflection Microscopy," Internal Memorandum and Special Research Report (December 1978).	NBS 5-35899
2895	A. Rønnekleiv, H.J. Shaw, and J. Souquet, "Scattering Theory for Surface Acoustic Wave Gratings," Technical Report (December 1978).	NSF ENG74-00334
2896	Staff, "Acoustic Techniques for Measuring Stress Regions in Materials," Three-Year Interim Report (April 1979).	EPRI RP609-1
2897	R.L. Byer and L.A. Shepp, "Two-Dimensional Remote Air-Pollution Monitoring Via Tomography," Reprint from Optics Letters, Vol. 4, No. 3, 75-77 (March 1979).	SRI 14307
2898	Staff, "Acoustic Techniques for Measuring Stress Regions in Materials," 36th Monthly Report for 1 - 30 November 1978 (December 1978).	EPRI RP609-1
2899	Staff, "Quantitative Modeling of Flaw Responses in Eddy Current Testing," Second Monthly Report for the period 15 November - 15 December 1978 (December 1978).	EPRI RP1395-3
2900	Staff, "Index of Reports" for the period January 1977 - September 1978 (December 1978).	--------
2901	Staff, "Processing of Optical Images with Optically Controlled Acoustic Transducers," Interim Technical Report for the period 15 June 1977 - 30 September 1978 (December 1978).	AFOSR 76-3059
2902	Staff, "Research Studies on Radiative Collision Lasers," Quarterly Report No. 7 for the period 10 September - 9 December 1978 (December 1978).	F19628-77-C-0072

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2903	Staff, "PVF_2 Transducers for Nondestructive Evaluation of Ceramics and Brittle Materials," Annual Report for the period 1 July 1977 - 30 June 1978 (January 1979).	AFOSR-77-3386
2904	S. Froyen and W.A. Harrison, "Universal Parameters in LCAO Theory," Preprint (December 1978). Preprint. To be published in Physical Review B.	NSF DMR77-21384
2905	Staff, "Acoustic Techniques for Measuring Stress Regions in Materials," 37th Monthly Report for the period 1 - 31 December 1978 (January 1979).	EPRI RP609-1
2906	W.R. Green, J. Lukasik, J.R. Willison, M.D. Wright, J.F. Young, and S.E. Harris, "Measurement of Large Cross Sections for Laser-Induced Collisions," Preprint (January 1979). Also: Published in Physical Review Letters, Vol. 42, No. 15, 970-973 (9 April 1979).	N00014-78-C-0403
2907	E.W. Weber and J.E.M. Goldsmith, "Anomalous Shifts of Hydrogen Balmer-α Fine Structure Lines in Helium," Preprint (January 1979). Also: Published in Physics Letters, Vol. 70A, No. 2, 95-98 (19 February 1979).	NSF PHY77-09687
2908	Staff, "Scanning Acoustic Microscope," Final Report covering the period 1 April 1975 - 30 September 1978 (January 1979).	NSF APR75-07317 A01
2909	Staff, "Acoustically Scanned Optical Imaging Devices," Semiannual Report No. 6 for the period 1 January - 30 June 1978 (Draft Copy) (July 1978).	N00014-76-C-0129
2910	J.C. White, G.A. Zdasiuk, J.F. Young, and S.E. Harris, "Observation of Atomic Pair Absorption with an Incoherent Source," Preprint (January 1979). Also: Published in Optics Letters, Vol. 4, 137-139 (May 1979).	F19628-77-C-0072

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2911	C.F. Quate, A. Atalar, and H.K. Wickramasinghe, "Acoustic Microscopy with Mechanical Scanning — A Review," Preprint (January 1979). To be published in the Proceedings of IEEE (August 1979).	AFOSR-77-3455 and NBS 5-35899
2912	Staff, "Tunable Optical Sources," Semi-annual Report No.3 for the period 1 July - 31 December 1978 (January 1979).	DAAG29-77-G-0221
2913	S.J. Brosnan and R.L. Byer, "Threshold and Linewidth Studies of Optical Parametric Oscillators," Preprint (December 1978). Also: Published in IEEE Journal of Quantum Electronics, Vol. QE-15, 415 (June 1979).	DAAG29-77-G-0221
2914	R.A. Baumgartner and R.L. Byer, "Optical Parametric Amplifiers," Preprint (December 1978). Also: Published in IEEE Journal of Quantum Electronics, Vol. QE-15, 432 (June 1979).	DAAG29-77-G-0221
2915	Staff, "Measurement of Surface Defects in Ceramics," Progress Report for the period March - December 1978 (January 1979).	N00014-78-C-0283
2916	B.T. Khuri-Yakub, A.G. Evans, and G.S. Kino, "Acoustic Surface Wave Measurements of Surface Cracks in Ceramics," Preprint (January 1979).	N00014-78-C-0283 and NSF ENG75-18681
2917	B.T. Khuri-Yakub, A.G. Evens, G.S. Kino, and B.R. Tittmann, "Acoustic Surface Wave Scattering: The Detection of Surface Cracks in Ceramics," Preprint (January 1979). Presented at the Ceramic Machining Symposium, Gaithersburg, Maryland (November 1978).	RISC RU74-20773
2918	A.E. Siegman, "Simplified Derivation of the Fokker-Planck Equation," Preprint (January 1979). To appear in American Journal of Physics.	-------

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2919	Staff, "Quantitative Modeling of Flaw Responses in Eddy Current Testing," Third Monthly Report for the period 15 December 1978 - 15 January 1979 (January 1979).	EPRI RP1395-3
2920	R.W. Falcone, "Laser Induced Energy Transfer," Internal Memorandum and Special Research Report (February 1979).	N00014-78-C-0403 and F19628-77-C-0072
2921	Staff, "Acoustic Microscopy at Cryogenic Temperatures," Status Report for the period 1 July 1978 - 1 January 1979 (January 1979).	N00014-77-C-0412
2922	Staff, "JSEP Achievements - 1961 - 1978 (Update of 15-Year Report dated September 1976) (February 1979).	N00014-75-C-0632
2923	Staff, "Acoustically Scanned Optical Imaging Devices," Semiannual Report No. 7 for the period 1 July - 31 December 1978 (February 1979).	N00014-76-C-0129
2924	Staff, "Research Support and Publications Activity for the Edward L. Ginzton Laboratory," (October 1978).	N00014-75-C-0632
2925	Staff, "Research on New Approaches to Optical Systems for Inertial Rotation Sensing," Interim Report for the period 1 October 1977 - 30 September 1978.	AFOSR-76-3070
2926	Staff, "Quantitative Modeling of Flaw Responses in Eddy Current Testing," Fourth Monthly Report for the period 15 January - 15 February 1979 (February 1979).	EPRI RP1395-3
2927	B.A. Auld and S. Ayter, "Acoustic Wave Scattering from Surface Cracks," Interim Report for the period 1 October 1978 - February 28, 1979 (February 1979).	RISC RI77-70946
2928	B.A. Auld, C. Eberspacher, A. Ezekiel, and D. Winslow, "Surface Flaw Detection with Ferromagnetic Resonance Probes," Interim Report for the period 1 October 1978 - 28 February 1979 (February 1979).	RISC RI77-70946

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2929	Staff, "Acoustic Techniques for Measuring Stress Regions in Materials," 38th Monthly Report for 1 - 31 January 1979 (February 1979).	EPRI RP609-1
2930	Staff, "Laser Induced Collisions and Techniques for Generation of VUV and Soft X-ray Radiation," Annual Report for the period 1 April 1978 - 31 March 1979 (March 1979).	N00014-78-C-0403
2931	A. Atalar, "Reflection Coefficient for a Lossy Liquid-Lossless Isotropic Solid Interface," Preprint (March 1979). To be published in the June 1979 issue of the Journal of the Acoustical Society of America.	F49620-78-C-0098
2932	Staff, "Ultrasonic Imaging and Signal Processing," Progress Report (March 1979).	RISC RI74-20773 (Task No. 1)
2933	Staff, "Ultrasonic Flaw Detection in Ceramics," Progress Report (March 1979).	RISC RI74-20773 (Task No. 2)
2934	Staff, "Investigation of Laser Dynamics, Modulation and Control by Means of Intra-Cavity Time Varying Perturbation," Semiannual Status Report No. 30 for the period 1 September 1978 - 28 February 1979 (March 1979).	NASA NGL 05-020-103
2935	Staff, "Acoustic Wave Transducers," Progress Report for the period April - December 1978 (March 1979).	NSF ENG77-28528
2936	W.R. Green, "Laser-Induced Interactions," Internal Memorandum and Special Research Report, March 1979.	N00014-78-C-0403
2937	N.W. Carlson, F.V. Kowalski, R.E. Teets, and A.L. Schawlow, "Identification of Excited States in Na_2 by Two-Step Polarization Labeling," Preprint (March 1979). Accepted for publication in Optics Communications.	NSF PHY77-09687
2938	Staff, "Acoustic Techniques for Measuring Stress Regions in Materials," 39th Monthly Report for 1-28 February 1979 (March 1979).	EPRI RP609-1

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2939	Staff, "Research Studies on Radiative Collision Lasers," Interim Technical Report for the period 10 March 1978 - 9 March 1979 (March 1979	F19628-77-C-0072
2940	Staff, "Research Studies on Radiative Collision Lasers," Quarterly Report No. 8 for the period 10 December 1978-9 March 1979 (March 1979).	F19628-77-C-0072
2941	A. Rønnekleiv, H.J. Shaw, and J. Souquet, "Design of Two-Dimensional Grating Acoustic Scanner for 41 μ Resolution," Technical Report (April 1979).	NSF ENG72-04217
2942	A. Rønnekleiv, H.J. Shaw, and J. Souquet, "Design of Two-Dimensional Grating Acoustic Scanner," Technical Report (April 1979).	NSF ENG72-04217
2943	Staff, "Quantitative Modeling of Flaw Responses in Eddy Current Testing," Fifth Monthly Report for the period 15 February - 15 March 1979 (April 1979).	EPRI RP1395-3
2944	J.E. Lawler, A.I. Ferguson, J.E.M. Goldsmith, D.J. Jackson, and A.L. Schawlow, "Doppler-Free Intermodulated Opto-Galvanic Spectroscopy," Preprint (April 1979). Also: Published in Physical Review Letters, Vol. 42, No. 16, 1046-1049 (16 April 1979).	NSF PHY77-09687 and N00014-78-C-0403
2945	W.R. Green, M.D. Wright, J.F. Young, and S.E. Harris, "Laser Induced Charge Transfer to an Excited Ionic State," Preprint (April 1979). To appear in the September 1979 issue of Optics Letters.	N00014-78-C-0403 and F19628-77-C-0072
2946	D.J. Jackson, J.E. Lawler, and T.W. Hansch, "Broadly Tunable Pulsed Laser for the Infrared Using Color Centers," Preprint (April 1979). To appear in Optics Communication.	N00014-78-C-0403

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2947	B.T. Khuri-Yakub and C.H. Chou, "Ultrasonic Attenuation of Piezoelectric PVF_2 Films at High Frequencies," Preprint (April 1979). To appear in Electronics Letters.	RISC RI74-20773
2948	M.R. Beasley, J.E. Mooij, and T.P. Orlando, "Possibility of Vortex-Antivortex Pair Dissociation in Two-Dimensional Superconductors," Preprint (February 1979). Also: Published in Physical Review Letters, Vol. 42, No. 17, 1165-1168 (23 April 1979).	NSF DMR75-04368
2949	J. Heiserman, C.F. Quate, and H.K. Wickramasinghe, "Acoustic Microscopy in Biophysics," Preprint (April 1979). To be published in Advances in Biological and Medical Physics, Vol. 17, 1979.	NIH 1 R01 GM 25826-01

LABORATORY CONTRACT AND GRANT SUPPORT

(Edward L. Ginzton Laboratory)

SOURCE - - CONTRACT/GRANT NO.	P.I.	TITLE	EXPIRATION DATE as of 6/30/79
I. Air Force Office of Scientific Research			
F49620-78-C-0009	Geballe	Film Synthesis and New Superconductors	9/30/80
F49620-77-C-0092	Siegman/Byer	Laser Physics and Laser Techniques	12/31/79
F49620-78-C-0098	Quate	Acoustic Microscopy for Nondestructive Evaluation of Materials	6/30/81
AFOSR-76-3059	Auld	Processing of Optical Images with Optically Controlled Acoustic Transducers	9/30/79
AFOSR-76-3070	Chodorow/Shaw	New Approaches to Optical Systems for Inertial Rotation Sensing	9/30/79
AFOSR-77-3386	Shaw	PVF_2 Transducers for Nondestructive Evaluation of Ceramics and Brittle Materials	6/30/80
AFOSR-78-3726	Kino	Research on Nondestructive Testing	8/31/79
Air Force Systems Command - Hanscom AFB			
F19628-77-C-0072	Harris/Young	Research Studies on Radiative Collision Lasers	1/9/80

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II. Public Health Service			
National Institutes of Health			
1 R01 GM25826-01	Quate	Acoustic Microscopy for Biomedical Applications	11/30/80
III. Department of Energy			
DE-AS03-76SF00326 PA # DE-AT03-76ER71043	Geballe/Beasley	Superconducting and Semi-conducting Properties of Electron Beam Evaporated Materials	1/31/80
IV. Department of the Army			
Army Research Office			
DAAG 29-77-G-0221	Harris/Byer	Tunable Optical Sources	8/31/79
V. National Science Foundation			
ENG77-01119	Chodorow	Nonlinear Generation of Sound in the Scanning Acoustic Microscope	7/14/79

SOURCE -- CONTRACT/GRANT NO.	P.I.	TITLE	EXPIRATION DATE as of 6/30/79
V. National Science Foundation (continued)			
PHY77-09687	Schawlow/Hänsch	Spectroscopy and Quantum Electronics	5/31/80
ENG78-10446	Chodorow/Young	Electron Beam Thin Film Deposition and Evaluation Facility	7/31/79
DMR77-21384	Harrison	Pseudopotential Methods in Physics	12/14/79
DMR76-21575	Geballe	Microscopic Parameters of Transition Metal Superconductors	8/31/79
ENG77-28528	Kino	Acoustic Wave Transducers	6/30/79 †
ENG77-28541	Auld	Variational Methods for Acoustic Wave Scattering and Propagation in Solids	6/30/79 †
PHY78-23532	Schawlow	Precision Optical Wavemeters	2/14/80
ENG78-18585	Quate	Acquisition of a Dilution Refrigerator for Acoustic Microscopy	1/14/80
VI. Electric Power Research Institute			
RP609-1-2	Kino/Shaw	Acoustic Techniques for Measuring Stress Regions in Materials	6/30/82
RP1395-3	Auld	Quantitative Modeling of Flaw Responses in Eddy Current Testing	10/14/80
VII. Environmental Protection Agency			
EPA 8-05750-1	Byer	Remote Atmospheric Measurement of SO_2 and CH_4 Using a $LiNbO_3$ Tunable Source	6/30/79

† Renewal Pending

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VIII. Navy			
N00014-76-C-0129	Kino	Acoustical Scanning of Optical Images	9/30/80
N00014-78-C-0283	Kino	Measurements of Surface Defects in Ceramics	2/28/81
N00014-78-C-0317	Weissbluth	Proton Transfer in Hydrogen-Bonded Nucleic Acids	9/30/79
N00014-78-C-0403	Schawlow	Advanced Laser Source Research	3/31/81
N00014-77-C-0412	Quate	Acoustic Microscopy of Cryogenic Temperatures	6/30/79
N00014-77-C-0439	Beasley	Superconducting Tunneling and Tunnel Applications in High TC A15 Superconductors	4/30/80
N00014-77-C-0582	Shaw	Piezoelectric PVF_2 Polymer Films and Devices	7/31/80
N00014-75-C-0632	Chodorow	Optical and Acoustic Wave Research-JSEP	3/31/81
N00014-79-C-0222	Auld	Elastic Domain Wall Waves in Ferroelectric Ceramics and Single Crystals	1/31/82
IX. National Aeronautics and Space Administration			
NGL 05-020-103	Harris/Siegman	Lasers and Laser Devices	3/31/80
NSG 2289	Byer	Application of CARS Spectroscopy to Turbulence Measurements	12/31/79
NSG 2372	Byer	Ultra High Resolution Molecular Beam CARS Spectroscopy with Applications to Planetary Atmospheric Molecules	12/31/79
NSG 7619	Harris/Siegman/ Young	Studies on Lasers and Laser Devices	3/31/80
X. Subcontracts			
Lawrence Livermore Laboratory			
3488009 (Prime:W-7405-ENG-48)	Byer	Research to Define Algorithms Appropriate to a High Data Rate Laser Wavelength Measuring Instrument	6/26/80
Rockwell International Science Center			
74-20773 (Prime:F33615-74-C-5180)	Kino	New Techniques for Acoustic Nondestructive Testing	9/30/79
77-70946 (Prime:F33615-74-C-5180)	Auld	Methods for the Detection and Characterization of Surface Flaws in materials	9/30/79

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Surface Waves	VUV and Soft X-Ray Light Sources	p-n Junctions Addressing
Optical Image Scanning	Laser Spectroscopy	Adaptive Antennas
Fiber Optics	High T_c Materials	
Signal Processing		

20. ABSTRACT (Continue on reverse side if necessary and identify by Block no.)

This report summarizes the research progress and activity on Joint Services Electronics Program Contract N00014-75-C-0632 for the period 1 April 1978 through 31 March 1979. Specific Projects are: (1) High-T_c Superconducting Weak-Link Josephson Junctions and Circuits (M.R. Beasley); (2) Acoustic Surface Wave Scanning of Optical Images (G.S. Kino); (3) Fiber Optic Signal Processing (H.J. Shaw); (4) Nonlinear Interactions of Acoustic Waves with Domains in Ferroic Materials (B.A. Auld); (5) Measurements of Ultrafast Physical Phenomena (A.E. Siegman); and (6) A VUV and Soft X-Ray Light Source (S.E. Harris and J.F. Young).

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